OPERATION BREAKTHROUGH

U.S. Department of Housing and Urban Development

A COMPENDIUM OF FIRE TESTING

5

VOLUME

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Foreword

Operation BREAKTHROUGH was initiated by the Department of Housing and Urban Development (HUD) in May 1969 to demonstrate industrialized techniques that could be used for the volume production of quality housing for all income groups. With this goal in mind, HUD selected 22 Housing System Producers to design and build housing prototypes on nine specially selected sites which represented a wide range of geographic, climatic and marketing conditions.

This compendium summarizes the tests conducted and the results obtained from the fire safety performance evaluation of the broad range of innovative materials and housing construction techniques that were used in the BREAKTHROUGH Program. It is hoped that this report will contribute to the advancement of current housing construction technology in addition to being of use to other organizations and individuals concerned with the fire safety of residential construction.

Charles J. Orlebeke
Assistant Secretary, Policy
Development and Research

BLES

1.

INTRODUCTION

range of housing concepts. Some were modifications of industrialized systems in use at the time; others were new concepts which showed great promise by virtue of innovative designs and applications of materials. The building systems employed by the various Housing System Producers participating in the BREAKTHROUGH Program were evaluated prior to prototype construction in terms of a set of recommended performance criteria developed for this purpose through the combined efforts of the National Bureau of Standards (NBS), the National Academies of Science and Engineering and HUD.

Since many of the life safety issues that are associated with innovative housing systems are related to fire safety considerations, considerable emphasis was placed in this area. Fire performance standards were established for all classes of residential occupancies from single family detached to multi-family dwellings. Due to limitations in the state-of-the-art of the performance concept, the criteria were based on the performance levels of conventional materials and designs that were known to have acceptable fire safety characteristics.

Conventional housing designs for which fire test data were already available were evaluated on the basis of a review of drawings, specifications, calculations and approved listings. However, extensive testing was required to determine the fire safety performance of systems which employed new materials and design concepts. In addition to flame spread and smoke generation tests conducted on interior finishes of walls, ceilings, cabinetry and floor coverings; properties such as the fire endurance of roof/ceiling, floor/ceiling and wall assemblies were determined.

This compendium of the fire testing conducted during Operation BREAKTHROUGH lists and describes the assemblies that were tested and the results that were obtained. Building researchers and product manufacturers, in addition to homebuilders and designers, should find this a useful resource document for the design of safe, quality housing.

The listing of a fire test and its results in this report should nc endorsement by HUD of any building component or assembly.

2.

FIRE ENDURANCE: WALL ASSEMBLIES

the BREAKTHROUGH housing, double wall constructions of unknown fire endurance were commonly encountered.

For these reasons a considerable amount of fire endurance testing was performed to determine compliance with the criteria set forth by HUD for the Operation BREAKTHROUGH Program. In some cases, several variations of the same basic design were tested. These variations represented either improvements in initial fire safety performance deficiencies or other product improvements.

2.1 Test Methods

Fire testing was generally conducted in accordance with Sections 10 through 14 of ASTM Standard E 119. These sections pertain to tests of bearing and non-bearing walls and partitions. The basic test procedure consists of: (1) mounting a typical wall assembly in the test frame of the furnace with the side to be exposed to the fire toward the furnace flames, (2) applying the appropriate load (if a bearing wall), and (3) raising the temperature of the fire on the exposed side in accordance with the standard time-temperature curve, shown in Fig. 2.1 together with the points on the curve that determine its character.

The fire endurance of the wall assembly is determined by the time required to reach the first occurrence of any one of the following:

1. Inability of the specimen to sustain the applied load (in the case of a loadbearing wall only).

2. Passage of flame or gases hot enough to ignite cotton waste on the unexposed side at the point of passage.

3. An average temperature rise of 250°F (139°C) above the initial temperature on the unexposed side, or a temperature rise of 325°F (181°C) at any one point on that side. Note: This criterion was not considered to be critical for the acceptance of exterior wall systems proposed for use in Operation BREAKTHROUGH.

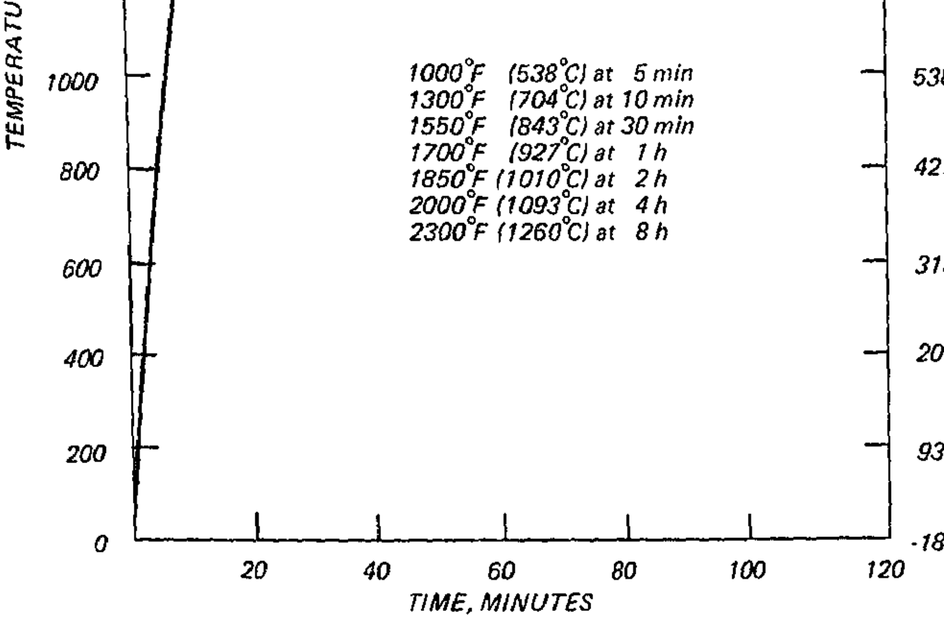


FIGURE 2.1
Standard ASTM E 119 Time-Temperature Curve

Due to factors such as the unique nature of modular construction and the phil
that actual fire hazard conditions should be simulated as closely as possib
following refinements were introduced into the testing program where applicabl

- Actual live and dead design loads as opposed to theoretical maximum loads were applied to loadbearing wall assemblies. Loading requiremen wall rated for use on the second story of a two-story house would be than the requirements for the same type of wall on the first story.

- The hose stream test suggested in ASTM E 119 was not required Operation BREAKTHROUGH Program, since primary emphasis was pl damage occurring during a fire that would affect the life safety occupants of the building rather than on the material damage that coul when a fire is extinguished.

- The fire endurance of an intra-dwelling interior wall assembly exposed to fire on *both* sides was determined (see Section 4.1). The data from this test were used to establish a basis of comparison with the data from the standard E 119 single side fire exposure test procedure.

- The NBS wall test furnace was operated with positive pressures over the upper two-thirds of the wall test specimens. The E 119 standard does not specify furnace pressures, and tests are commonly conducted with negative pressures. Under positive furnace pressures, which more closely represent the conditions that occur in actual building fires, gases are forced through fissures or openings in the wall assemblies. Wall tests discussed in this compendium that were not conducted at NBS (i.e., do not have an NBS reference) generally did not use positive furnace pressures.

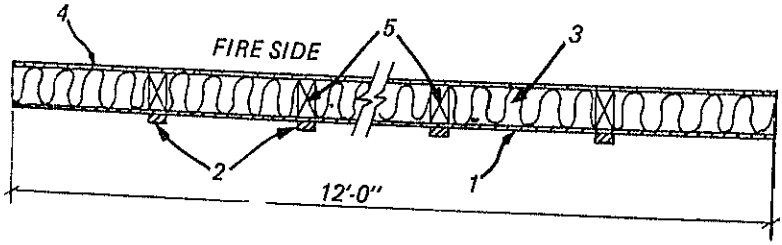
REF: *Standard Methods of Fire Tests of Building Construction and Materials*, ASTM E 119, *1971 Annual Book of ASTM Standards*, Part 14.

Systems Evaluated and Results

2.2.1 Exterior Wall Assemblies

The wall systems in this category were single leaf constructions intended for use as the loadbearing exterior enclosures of single family detached housing units or of multifamily low-rise housing, such as garden apartments. The specimens tested included several different types of sandwich panels and a number of wood stud and steel stud walls.

other signs of failure.



Construction

1. 3/8-in exterior grade plywood siding, applied vertically, attached to studs w nails spaced 6 in o. c. along the edges and 12 in o. c. at intermediate f members.
2. 3/4 by 2-in wood battens 16 in o. c. nailed in line with studs at 16 in o. c.
3. 3 1/2-in glass fiber insulation stapled to studs.
4. 5/8-in type X gypsum wall board applied vertically, glued to studs with ne adhesive and attached with 4d S 449 DX nails spaced 6 in o. c. at the per and at intermediate members. Joints taped with fiberglass mesh tape and sp and nails spackled.
5. 2 by 4 studs spaced 16 in o. c.

Notes: Wall specimen was 8 ft 3/8 in high. Board joints were located at studs. 2 x stops between studs at midheight of wall panel.

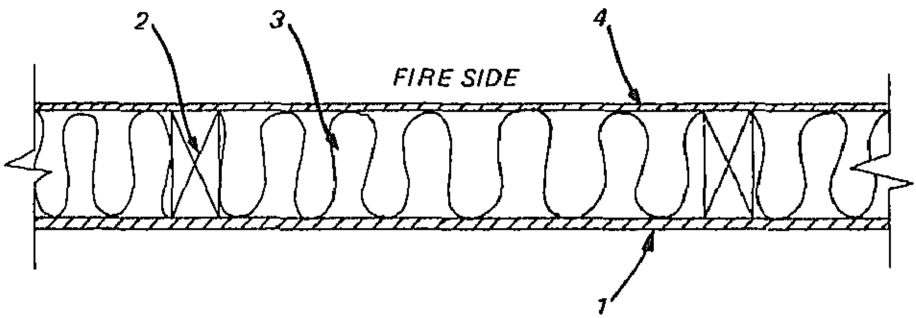
FIGURE 2.2
Horizontal Section of Exterior Wall Assembly

REF: Baron, F.M. and Williamson, R.B., *Standard Fire Test of a Wood Stud Ex Bearing wall*, Structural Research Laboratory Report No. 72-9, Universi California, Berkeley, California, July 1972 (NTIS Accession No. PB 212 703*

*Available from National Technical Information Service, 5285 Port Royal Springfield, Va. 22151.

Test Results:

Failure occurred at 15 min 45 s by flame-through near the middle of one of the center plywood sheets. Shortly thereafter, excessive temperature rises, both average and individual, were recorded on the unexposed side. The test *was terminated at 26 min 20 s to avoid structural collapse.*



Construction

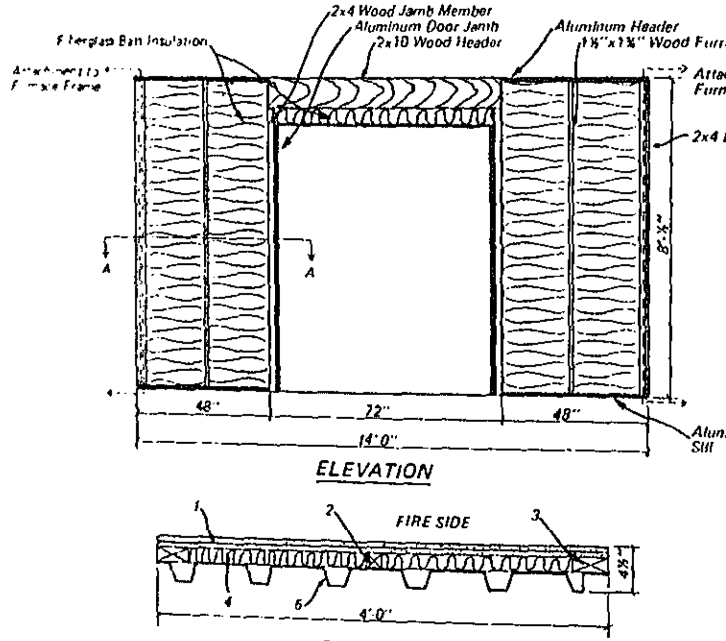
1. 3/8-in exterior grade A-C plywood attached with 6d common nail 6 in o. c along the edges and 12 in o. c. at intermediate framing members.
2. 2 by 4 wood studs, 16 in o. c. nailed to 2 by 4 top and sole plates with 16d common nails.
3. 3 1/2-in glass fiber insulation stapled to studs with aluminum backing toward interior (fire) side.
4. 1/4-in interior grade C-D plywood attached with 4d finishing nails 8 in o. c. throughout.

Notes: 2 by 4 fire stops between studs at midheight of wall panel. Plywood boards installed vertically, with joints located at studs and not staggered.

FIGURE 2.3
Horizontal Section of
Exterior Wall Assembly

REF: Son, B.C., *Fire Endurance of a Conventional Plywood Faced, Wood Stud Exterior Wall Containing Fiberglass Insulation Batts,* NBS Report 10 407 (Revised October 1972), National Bureau of Standards, Washington, D. C. 20234. (NTIS Accession No. PB-214 781)

Flame-through occurred at the top of the door frame at 54 min, followed by structural failure at 55 min.



Construction

1. Two layers of 5/8-in type X gypsum wall board installed vertically, with joints staggered. Each layer individually fastened to the wood furring and wood members with No. 10 self-threading nails 10 in o. c.
2. 2 by 2 wood furring strips 24 in o. c.
3. 2 by 4 wood door jamb and panel edge.
4. 2 1/2-in glass fiber batts compressed into 1 1/2-in cavity.
5. 0.026 in corrugated aluminum exterior siding glued to wood members with code-approved construction adhesive.

Notes: The test specimen was 14 ft long and 8 ft 1/2 in high, with one wall panel on each side of a 6-ft door opening covered with three layers of 5/8-in type X gypsum board. 2 x 10 wood header installed above aluminum door frame installed in the opening. Top and bottom of panel sealed with extruded aluminum header and sill.

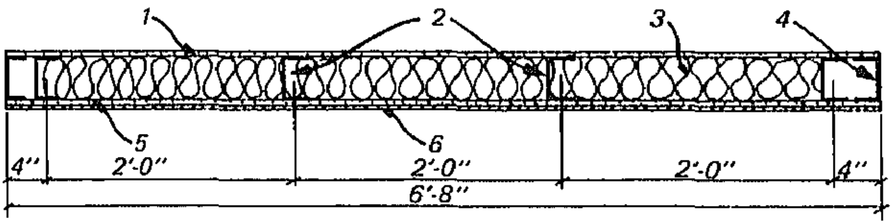
FIGURE 2.4
Exterior Wall Assembly with Door Opening

REF: Son, B. C., *Fire Endurance of a Corrugated Aluminum Sheet and Gypsum Board Exterior Wall Assembly*, NBS Report No. 10 418, National Bureau of Standards, Washington, D. C., 20234. (NTIS Accession No. PB-217 365)

Test Results:

The test of wall 1 was terminated after 78 min when the specimen was unable to sustain the load. However, an excessive temperature rise of 325°F (181°C) was recorded at a screw head on the unexposed side after 63 min.

The test of wall 2 was terminated at 60 min, although a temperature rise of 325°F on a screw head on the unexposed side was recorded at 53 min.



Construction

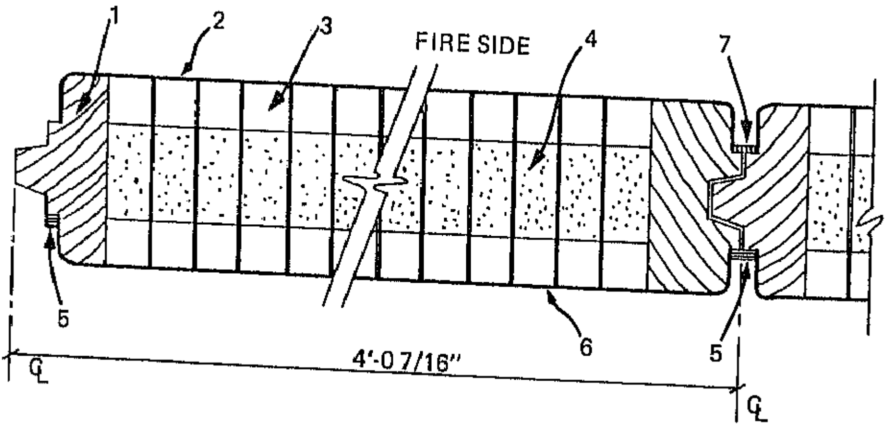
1. 5/8-in type X gypsum wall board installed vertically and attached to studs with 1-in type S-12 screws spaced 8 in o. c. along the edges and 12 in o. c. at intermediate framing. Joints taped and spackled and screw heads spackled.
2. 18 ga steel studs spaced 24 in o.c. and welded to 24 ga runner track on top and bottom.
3. 3 1/2-in thick glass fiber insulation batts.
4. 25 ga steel studs at each end of panel.
5. 1/2-in firecode gypsum sheathing installed vertically and attached with 1-in type S-12 screws spaced 12 in o. c. along the edges and 16 in o. c. at intermediate framing members.
6. 3/8-in A-C exterior grade plywood installed vertically and attached with 1 5/8-in type S-12 screws spaced 8 in o. c. along the edges and 12 in o. c. at intermediate framing members.

Note: Plywood and gypsum sheathing joints located along studs and staggered.

FIGURE 2.5
Horizontal Section of
Exterior Wall Assembly

REF: Report, United States Gypsum Research Center, Des Plaines, Illinois, April 1971. (Unpublished)

An excessive temperature rise at one point on the unexposed surface occurred at 7 min 50 s. Load failure occurred at 23 min, and flame-through occurred at 26 min at a joint between an end panel and the adjacent panel after the gas had been shut off at 23 min 30 s.



Construction

1. T and G wood end pieces (top and bottom surrounds are not T and G) attached to steel sheets with 14 ga 5/8-in staples at 12 in o.c.
2. 26 ga galvanized sheet steel on interior surface attached to the paper honeycomb core with epoxy adhesive.
3. 3-in thick phenolic resin impregnated paper honeycomb core with 3/4-in hexagonal cores.
4. 1 1/2-in rigid polyurethane insulation pressed into the honeycomb core.
5. 1/4 by 1/4-in butyl sealant.
6. 26 ga galvanized sheet steel finished with baked-on silicone paint on exterior surface and attached to the paper honeycomb core with epoxy adhesive.
7. Tongue and grooved joint on interior is sealed with 1/16 by 3/8-in vinyl tape.

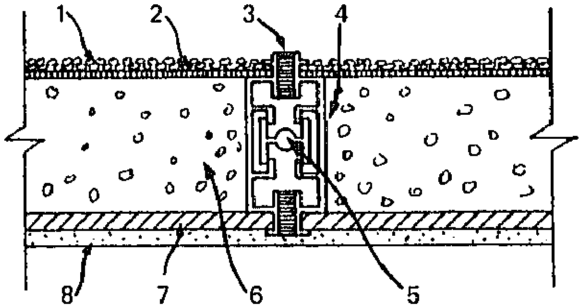
FIGURE 2.6
Horizontal Section of Exterior Wall Assembly

REF: Son, B.C., *Fire Endurance Tests of Steel Sandwich Panel Exterior Wall and Roof/Ceiling Construction*, NBSIR 73-135, National Bureau of Standards, Washington, D.C. 20234, January 1972. (NTIS Accession No. PB-221 310)

exterior face was fire exposed to ascertain the time that it would take for a fire to spread from one dwelling into another of the same type that is located immediately adjacent.

Test Results:

Impending failure under load due to excessive lateral deflection made it necessary to terminate the test after 23 min 30 s of exposure to fire. No excessive temperature rises were recorded on the unexposed side.



Construction

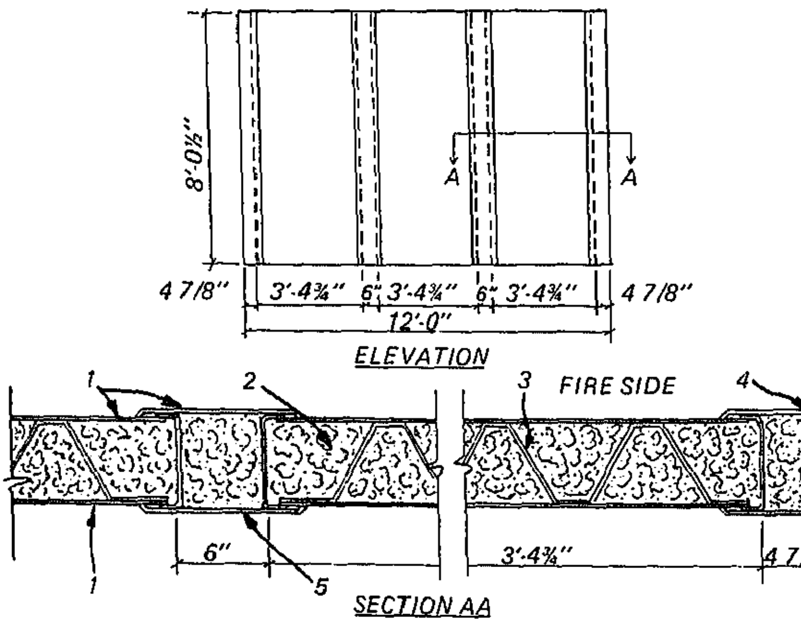
1. Stone aggregate set in epoxy matrix.
2. 1/8-in cement-asbestos board force-fit to the aluminum perimeter frame of the panel.
3. Synthetic rubber wedge.
4. Aluminum perimeter frame.
5. Aluminum "H" spline.
6. 3-in polyurethane foamed in place.
7. 5/16-in plywood force-fit to the aluminum perimeter frame of the panel.
8. 5/8-in type X gypsum wall board fastened to plywood with 1 1/8-in Type S bugle head screws spaced 4 in o. c. horizontally and 12 in o. c. vertically with first line of screws placed 6 in from the top and bottom edges of the assembly. Gypsum boards were installed after the four panels were placed in the test furnace frame. Panel joints and gypsum board joints were staggered.

FIGURE 2.7
Detail of Panel
Surround and Joint

REF: Son, B. C., *Fire Endurance Test of an Exterior Sandwich Panel Wall Assembly*, NBS Report 10 416, National Bureau of Standards, Washington, D.C. 20234. (NTIS Accession No. PB-217 363)

Test Results:

Specimen was loaded with 700 lb/ft. After 30 min of exposure, an exc
temperature rise occurred at an individual point on the unexposed su
The test was continued for an additional 60 min. When terminated af
min of exposure, the temperatures of none of the other thermocoup
the unexposed side had exceeded the permissible limits prescribed in
E 119, and the wall was sustaining the load satisfactorily.



Constuction

1. 0.080-in thick glass fiber reinforced polyester laminate bonded to stiffene adhesive.
2. Mineral wool insulation packed into all cavities. Sodium silicate and water
3. 0.050-in thick corrugated stiffeners made from same glass fiber rei polyester as 1.
4. Wall end stub molded from same composite material as stiffeners and lar facing sheets.
5. Straight joint.

FIGURE 2.8
Details of Test Specimen

REF: Williamson, R. B. and Baron, F. M., *Fire Test of Fiberglass Reinforced Structural Wall Panel*, Structural Research Laboratory Report No. 71-4, Un of California, Berkeley, California, June 1971. (NTIS Accession No. PB-222

of the other. Therefore, in the fire tests of the loadbearing double walls, a split loading bolster was employed, which permitted each leaf of the wall assembly to be loaded separately (see Fig. 2.10).

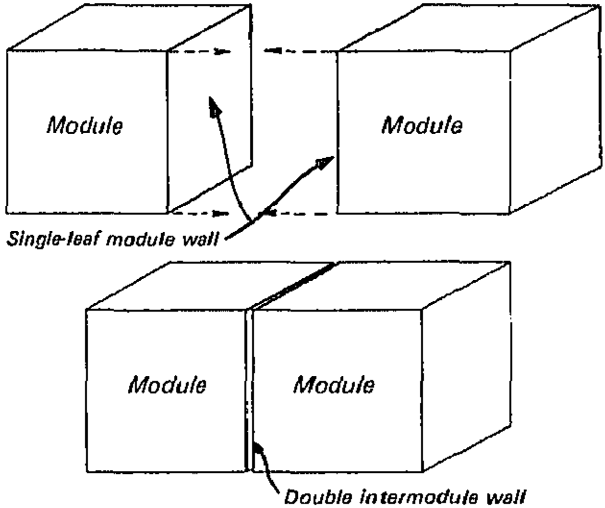


FIGURE 2.9
Intermodule Double Wall Assembly

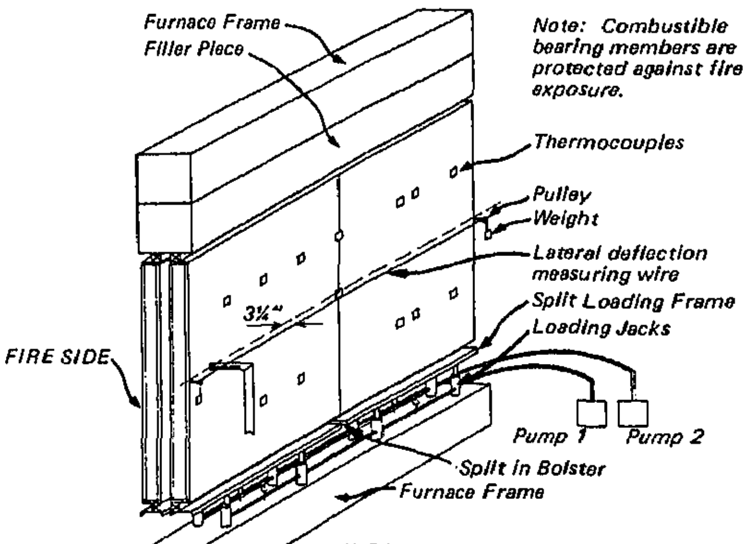
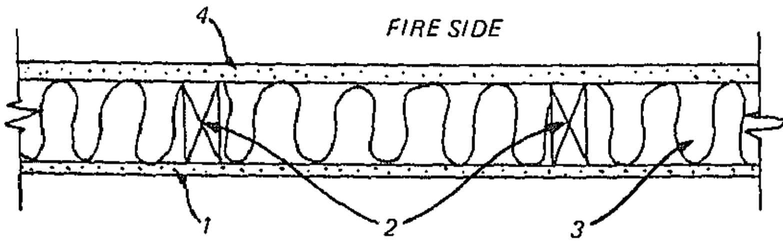


FIGURE 2.10
Schematic Drawing of Split Bolster Loading Set-Up

Test Results:

Although flame-through occurred at 1 hr 7 min, when the test terminated, the wall had met all E 119 criteria for a 1 hr fire endu rating at 60 min.



Construction

1. 1/2-in non-rated gypsum wall board.
2. 2 by 4 wood studs 16 in o. c.
3. 3 1/2-in thick glass fiber insulation stapled into the spaces between studs.
4. 5/8-in type X gypsum wall board.

Notes: Gypsum board first glued to the studs with neoprene adhesive and then n the studs and 2 x 4 floor and ceiling runners with #4 ring shank nails at 16 in wall board joints and nails taped and spackled with 14 by 12-in ground fibergla and joint compound conforming to ASTM G-475. 2 x4 fire stops between s mid-height.

FIGURE 2.11
Horizontal Section of One Leaf of an Intermodule Double Wall

REF: Williamson, R. B., Mino, O., Dwelle, J.C., *Standard Fire Test of a Woo One-Hour Bearing Wall Assembly*, Structural Research Laboratory Rep 72-11, University of California, Berkeley, California, September 1972 Accession No. PB 212 808).

unexposed side of the first wall at one end of the frame, forming a double wall with a 2 3/4-in air space between the two walls (see Fig. 2.12). The test was designed to obtain the fire endurance rating of both the single and double wall construction in one test.

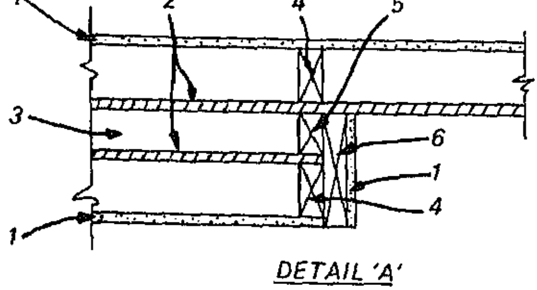
Each leaf of this assembly consisted of 2 by 4 wood studs, 16 in o.c. The exterior of the wall (facing the cavity side) was sheathed with 1/2-in plywood, while the interior, or exposed face, was 5/8-in type X gypsum wall board.

Test Results:

The single wall segment failed at 43 min when the average temperature rise on its unexposed face exceeded 250°F (139°C).

It was necessary to terminate the test at 47 min when flame penetration was observed at the top of the air space separating the two walls. The test results of the double wall segment, therefore, were inconclusive, although, based on judgment, it was estimated to have a fire endurance of 1 hr 2 min.

REF: Son, B.C., *Fire Endurance Test of Plywood Faced Exterior Walls for Single Family Housing*, NBSIR 73-140, National Bureau of Standards, Washington, D.C. 20234, March 1973. (NTIS Accession No. PB-220 226)



Construction

1. 5/8-in type X gypsum wall board.
2. 1/2-in exterior grade A-C plywood.
3. 2 3/4-in air space.
4. 2 by 4 wood studs, 16 in o.c.
5. 2 by 2 3/4-in wood closure.
6. 2-in wood closure.

FIGURE 2.12
Horizontal Section of an Intermodule Double Wall

The basic construction (see Fig. 2.13) consisted of 2 by 3 wood studs 16 in o.c. with 2 layers of 1/2-in type X gypsum board on the room side of the wall and no sheathing nor insulation on the exterior side. The test assembly consisted of two identical 16-ft long by 8-ft high walls, made up of two 6-ft long panels separated by a 3-ft 4 1/2-in wide infill panel. Two different types of field applied, infill panel joint closure systems were included: one covered with wood trim and one with gypsum board.

Test Results:

The overall fire endurance of the assembly was 2 hr 19 min, with failure by excessive temperature rise at one point on the unexposed surface of the assembly.

Failure of the fire-exposed wall leaf occurred at 1 hr 17 min, when flame penetrated through a gypsum board joint.

Neither of the two joints failed during the test, although it was apparent that the joint covered with wood trim would have failed before the one protected with gypsum board.

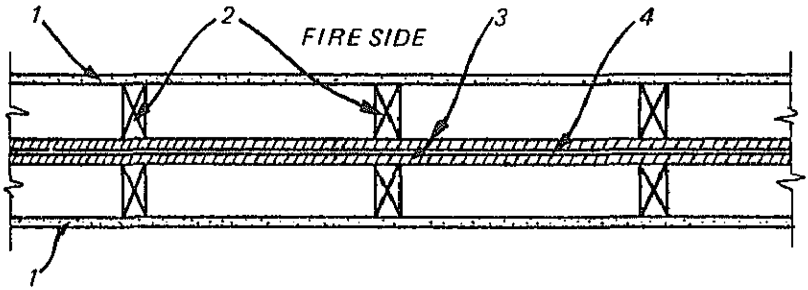
REF: Son, B. C., *Fire Endurance of a Wood Stud Interdwelling Double Wall Construction*, NBSIR 73-169, National Bureau of Standards, Washington, D.C. 20234, April 1973. (NTIS Accession No. PB-221 185)

Construction

1. 2 layers 1/2-in type X gypsum wall board. Base layer applied with 1 1/2-in bright ring-shank nails 12 in o.c. Face layer glued to base layer with construction adhesive and secured with 7d cement-coated box nails on 24-in centers. Joints of base and face layer were staggered.
2. 2 by 3 wood studs on 16-in centers with 2 by 3 wood top and bottom plates.
3. 2 by 2 wood filler.
4. 2 layers 1/2-in plywood.
5. 1/2-in space between wall panels.
6. 1/2-in type X gypsum board on top and bottom plates and at vertical joints.
7. 2 by 6 closure.
8. 2 by 4 battens at joints.
9. Wood archway trim.
10. 1/2-in regular gypsum board.

FIGURE 2.13
Horizontal Section of an Intermodule Double Wall

temperature at one point on the unexposed side exceeded 325 F (181 C).

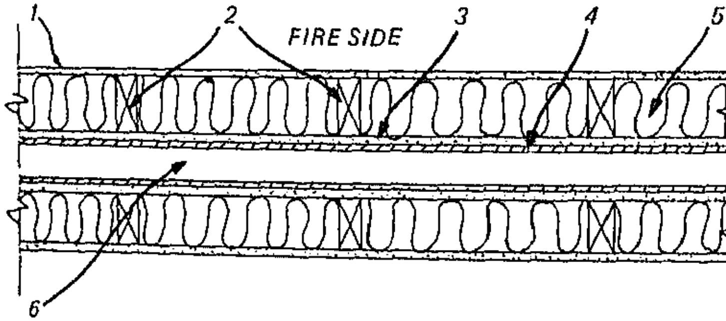


Construction

1. 5/8-in type X gypsum wall board attached to framing members by gluing with construction adhesive and nailing with 4d ring-shank nails 16 in o. c.
2. 2 by 4 wood studs, 16 in o. c., with 2 by 4 top and bottom plates.
3. 1/2-in plywood attached to framing members by gluing with construction adhesive and nailing with 8d wire shank nails 6-in o. c. along the edges and 12 in o. c. at intermediate framing members.
4. 1/2-in air space.

FIGURE 2.14
Horizontal Section of an Intermodule Double Wall

REF: Baron, F. M., Williamson, R. B., and Conklin, J. H., *Structural Research Laboratory Report No. 72-4,* University of California, Berkeley, California, January 1972. (Unpublished)



Construction

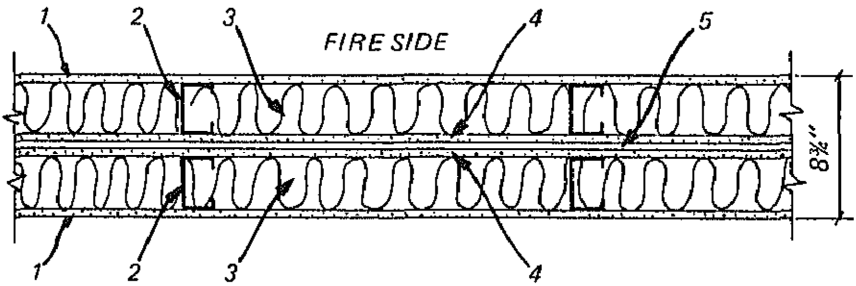
1. 1/2-in type X foil-backed gypsum wall board.
2. 2 by 4 wood studs, 16 in o.c.
3. 1/2-in type X gypsum wall board.
4. 3/8-in plywood.
5. 3 1/2-in thick glass fiber insulation batts.
6. 2-in air space.

FIGURE 2.15
Horizontal Section of an Intermodule Double Wall

REF: Fire Test Report WP-245, *National Gypsum Company, Decemb* *(Unpublished).*

Test Results:

The fire endurance of the wall assembly was 42 min, when the fire exposed wall could not sustain the load. The test was continued and the unexposed wall failed similarly at 1 hr 13 min. Flame penetration to the unexposed surface occurred at 1 hr 15 min.



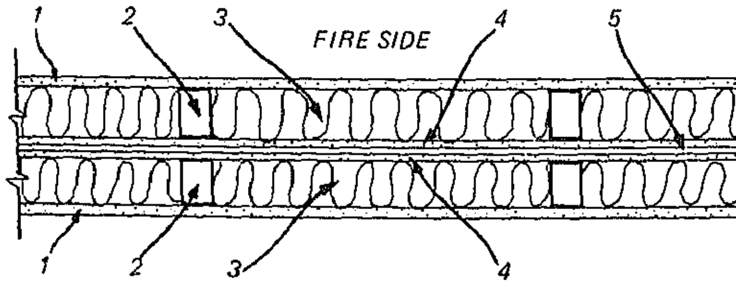
Construction

1. 5/8-in type X gypsum wall board installed vertically and attached to steel framing members with 1-in type S-12 bugle head screws spaced 12 in o.c. at intermediate framing members and 8 in o.c. along the edges. Joints were taped and spackled.
2. 3-in by 1 3/4-in cold-rolled, 18 ga steel "C" studs, 24 in o.c. and welded at top and bottom to 3 1/8 by 1 1/8-in steel channels, 1/16 in thick.
3. 2 1/2-in thick friction-fit glass fiber insulation batts.
4. 1/2-in type X gypsum wall board installed vertically and attached to steel framing members with 1-in type S-12 bugle head screws spaced 12 in o.c. at intermediate framing members and 8 in o.c. along the edges.
5. 1/2-in air space.

FIGURE 2.16
Horizontal Section of an
Intermodule Double Wall

REF: Son, B.C. and Shoub, H., *Fire Endurance Tests of Double Module Walls of Gypsum Board and Steel Studs,* NBSIR 73-173, National Bureau of Standards, Washington, D.C. 20234, April 1973. (NTIS Accession No. COM 73-10844)

exposed to the fire failed under load. Failure by passage of
through the entire wall assembly occurred at 1 hr 37 mir
unexposed wall member failed under load at 1 hr 43 min.



Construction

1. 5/8-in type X gypsum wall board installed vertically and fastened
with 1-in type S-12 bugle head screws spaced 8 in o.c. along the edg
o.c. at intermediate framing members. Joints were taped and spackled.
2. 3 by 2 by 0.065-in tubular steel studs, 24 in o.c. and welded on top a
3 1/8 by 1 1/8-in steel channels, 1/16 in thick.
3. 3 1/2-in thick glass fiber insulating batts compressed into 3-in cavity.
4. 1/2-in type X gypsum wall board installed vertically and fastened
with 1-in type S-12 bugle head screws spaced 8 in o.c. along the edg
o.c. at intermediate framing members.
5. 1/2-in air space.

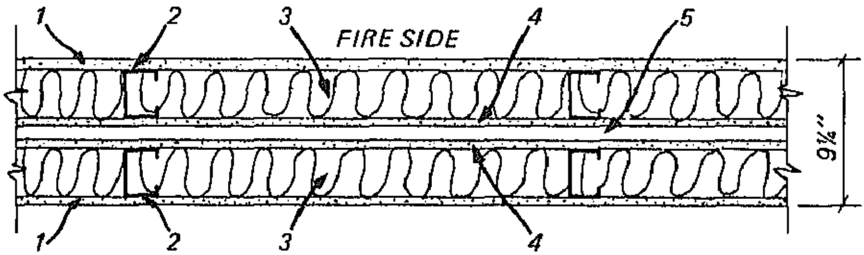
FIGURE 2.17
Horizontal Section of an Intermodule Double Wall

REF: Son, B.C. and Shoub, H., *Fire Endurance Tests of Double Module Wa Board and Steel Studs,* NBSIR 73-173, National Bureau of Standard D.C. 20234, April 1973. (NTIS Accession No. COM 73-10844)

5. A load of 680 lb/ft was applied during the test instead of 1078 lb/ft since the wall was representative of the first-story wall of a two-story unit rather than the three-story unit referred to in 2.2.2.6.

Test Results:

The fire endurance time of the wall assembly was 2 hr 8 min when the fire exposed wall of the assembly failed under load.



Construction

1. 5/8-in type X gypsum wall board applied vertically. Attached with 1-in type S-12 drywall screws spaced 8 in o.c. along the edges and 8 to 10 in o.c. along intermediate framing members. Joints finished with tapeless joint compound.
2. 3 by 1 3/4-in 16 ga galvanized steel "C" studs, 24 in o. c.
3. 3 1/2-in thick glass fiber, paper-backed insulating batts.
4. 1/2-in type X gypsum wall board applied vertically with type S-12 drywall screws spaced 8 in o. c. along the edges and at intermediate framing members. Joints were offset 24 in from the 5/8-in gypsum wall board.
5. 1-in air space.

FIGURE 2.18
Horizontal Section of an Intermodule Double Wall

REF: *Fire Test Report WP-254,* National Gyp
New York 14217, January 1972. (Unpubli

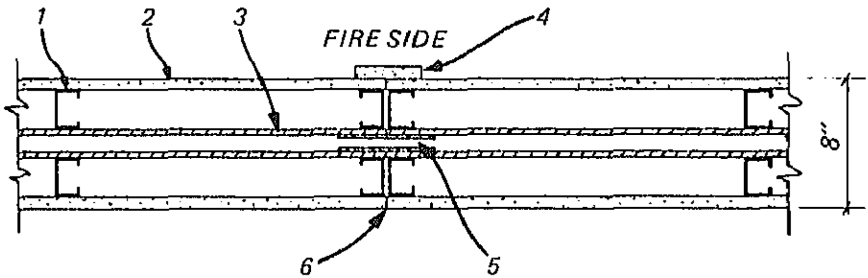
Test Results:

Structural failure of the fire-exposed leaf under the 680 l
occurred at 2 hr 9 min.

REF: Gauntlett, J. F., *Fire Test of Inter-Dwelling Wall,* Test Repor
Gypsum Company Research Center, Buffalo, New Yo
(Unpublished).

Test Results:

The fire endurance of the double wall assembly was 1 hr 23 min, at which time the wall on the fire exposed side failed under load. The plaster on the unexposed wall delaminated immediately after the first wall failed, and flaming occurred through a large gap at the top of the panel at 84 min, followed almost immediately by structural collapse.



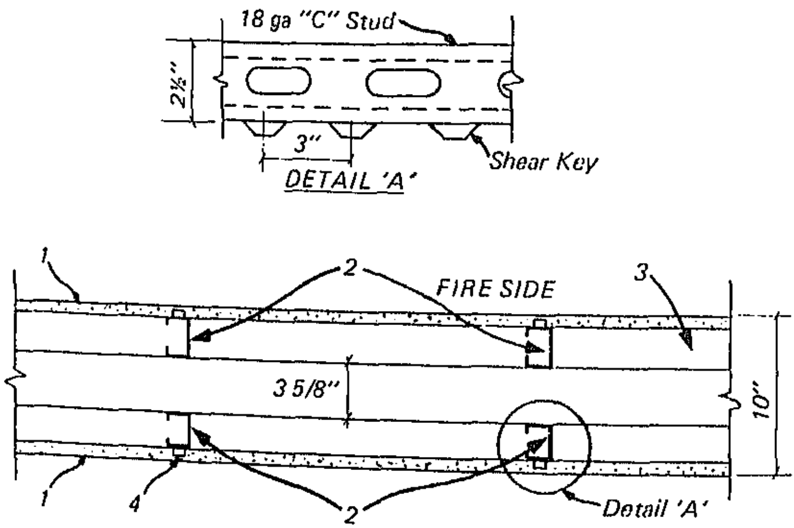
Construction

1. 2 1/2 by 1 5/8-in 18 ga steel "C" studs, 24 in o. c.
2. 5/8-in nominal (11/16-in actual) cast glass fiber reinforced vermiculite plaster mix.
3. 3/8-in standard (C-D) grade plywood, with exterior glue, nailed to steel studs with 1 1/2-in galvanized annular nails on 6-in centers.
4. Panel joint on exposed side covered with 4-in wide strip of 5/8-in type X gypsum board attached through plaster to the studs with 2-in long type G bugle head laminating screws.
5. Panel joint on plywood side covered with 6-in wide strip of 3/8-in C-D grade plywood, with exterior glue, nailed with 6d common nails on 12-in centers.
6. Panel joint in cast plaster packed with mineral wool and finished with perlite plaster.
7. Cast plaster attached to 2-in wide strips of corrugated wire lath stapled along the steel studs with 1/2-in #18 round tinned high carbon wire staples on 12-in centers.

FIGURE 2.19
Horizontal Section of an
Intermodule Double Wall

REF: Son, B. C., *Fire Endurance Test of an Interdwelling Double Wall Assembly for Single Family Housing,* NBS Report 10417, National Bureau of Standards, Washington, D.C. 20234. (NTIS Accession No. PB-217 364)

The fire endurance of the test assembly was 2 hr 43 min, reached when the temperature rise at one point on the unexposed side exceeded the maximum permitted by ASTM E 119.



Construction

1. 11/16-in cast glass fiber reinforced vermiculite plaster, attached to the steel studs through shear keys (see Detail 'A').
2. 2 1/2 by 1 5/8-in 18 ga steel "C" studs, 24 in o. c.
3. 2 1/2 by 1 3/4-in 20 ga steel channel top and sole plates welded to studs.
4. Shear keys stamped on 3 in centers in metal studs (Detail 'A').

FIGURE 2.20
Horizontal Section of an Intermodule Double Wall

REF: *Report No. 5047*, Building Research Laboratory, Engineering Experiment Station, Ohio State University, Columbus, Ohio 43210, January 1973. (Unpublished)

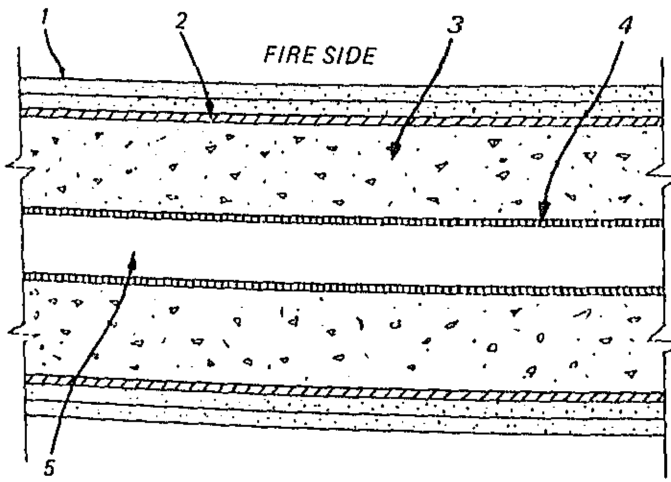
The fire endurance time of the wall assembly was 2 hr 29 min, at which time the wall exposed to the fire could no longer sustain the applied load.

REF: *Report No. 5048,* Building Research Laboratory, Engineering Experiment Station, Ohio State University, Columbus, Ohio 43210, July 1973. (Unpublished)

in Figure 2.7 to provide a wall panel
panels, separated by a 2-in air space, made up the test wall assemb
of 735 lb/ft was applied to each wall during the test.

Test Results:

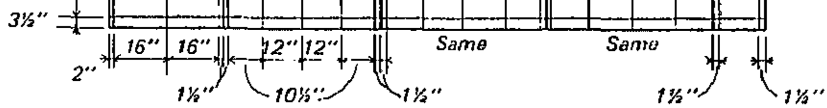
The fire endurance time of the double wall system was 1 hr 4 min
time the exposed wall became unable to sustain the applied load
was discontinued at 1 hr 6 min because of untenable conditions
building, resulting from smoke and combustion gases release
polyurethane foam insulation in the wall assembly.



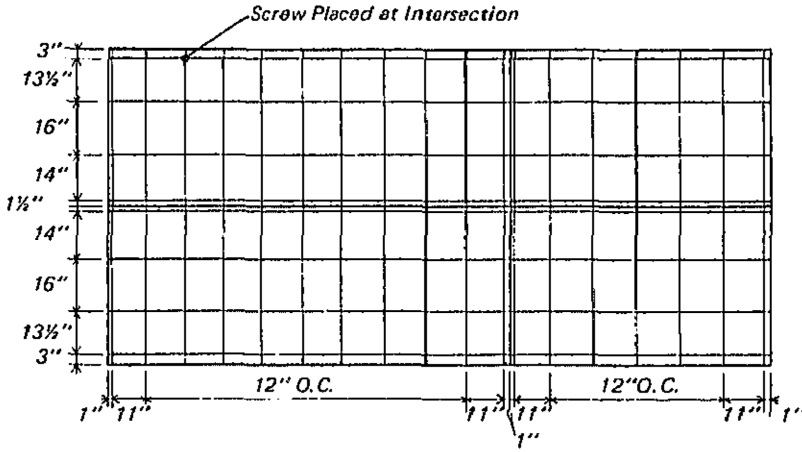
Construction

1. Two layers of 1/2-in type X gypsum wall board fastened to plywood bugle head screws in pattern indicated in Figure 2.21b.
2. 5/16-in plywood force-fit to aluminum perimeter frame.
3. 3-in polyurethane foamed in place.
4. 1/8-in cement-asbestos board force-fit to aluminum perimeter frame.
5. 2-in air space.

FIGURE 2.21a
Horizontal Section of an Intermodule Double Wall



FIRST LAYER OF ½" TYPE X



SECOND LAYER OF ½" TYPE X

FIGURE 2.21b
Fastener Schedules

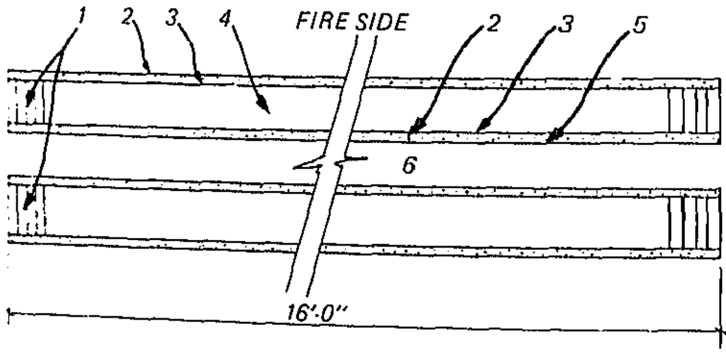
REF: Son, B. C., *Fire Endurance Test of an Interdwelling Double Wall Constructed of Polyurethane Foam-Filled Sandwich Panels*, NBSIR 73-170, National Bureau of Standards, Washington, D.C. 20234, April 1973. (NTIS Accession No. PB-221 193)

bonded type X gypsum board, 2)
the air space sprayed with polyester resin containing chopped glass

Each 16-ft-long wall panel was loaded with 636 lb/ft.

Test Results:

Fire endurance time for the complete wall assembly was 1 hr 19 m
determined by the observed collapse of the interior face of the u
wall. The exposed wall failed at 1 hr 5 min 30 s by flame-through.



Construction

1. End closures of 4 layers of 3/4-in plywood.
2. 5/8-in type X gypsum wall board adhesively bonded to each face of th
   core with polyester base adhesive. All joints between gypsum boards
   and filled with plaster joint compound. Joints not staggered.
3. Skin of woven glass fiber roving (5 x 4 count, 20 oz, 0.04 in thick) i
   with polyester resin.
4. 3-in thick paper honeycomb core treated with flame retardant.
5. Sprayed polyester resin containing chopped glass fibers (applied only
   board facing the air space).
6. 2 3/4-in air space.

FIGURE 2.22
Horizontal Section of an Intermodule Double Wall

min.

REF: *Fire Test Report WP-212,* National Gypsum Company, Buffalo, New York, May 1971. (Unpublished)

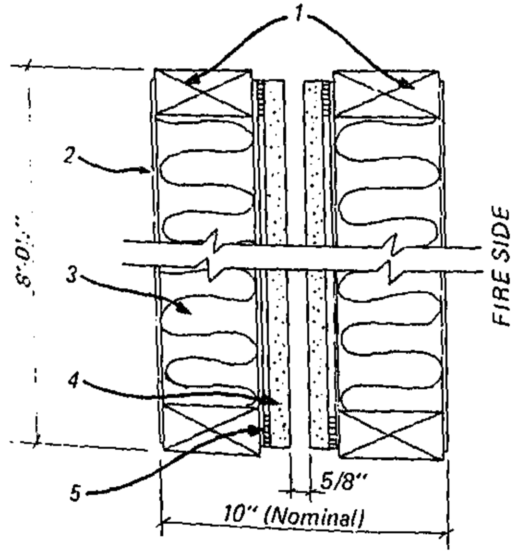
The exposed wall failed under load at 1 hr [illegible] min, while the unexposed failed structurally at 1 hr 43 min.

REF: *Fire Test Report WP-221*, National Gypsum Company, Buffalo, New York, 1971. (Unpublished)

Structural failure of the fire exposed wall occurred at 27 min 25 s. Maximum permissible temperature rise occurred on the unexposed surface of the other wall at 42 min.

REF: Son, B.C., *Fire Endurance Test of a Fiber Glass Reinforced Polyester Double Wall Assembly*, NBSIR 73-168, National Bureau of Standards, Washington, D.C. 20234, April 1973. (NTIS Accession No. PB-221 184)

The fire endurance time of the wall assembly was 1 hr 39 min, the temperature rise at one thermocouple on the unexposed the permissible limit of 325°F (181°C). The exposed wall under load at 1 hr 5 min. The test was terminated at 1 hr 44 flame-through occurred at the unexposed face of the remaini



Construction

1 2 by 4 wood plates top and bottom.
2 0.08-in glass fiber reinforced polyester structural laminate adh corrugated stiffener.
3 Glass fiber reinforced polyester corrugated stiffeners (vertically) with rock wool insulation containing a binder of sodium sil Intumescent paint applied to stiffener (except where bonded to
4 5/8-in type X gypsum wall board installed vertically, bonded a joints between FRP panels. Joints in layers on opposite sides cavity staggered by 24 in o. c.
5 3/16-in thick asbestos mill board furring strips used as sealer top a

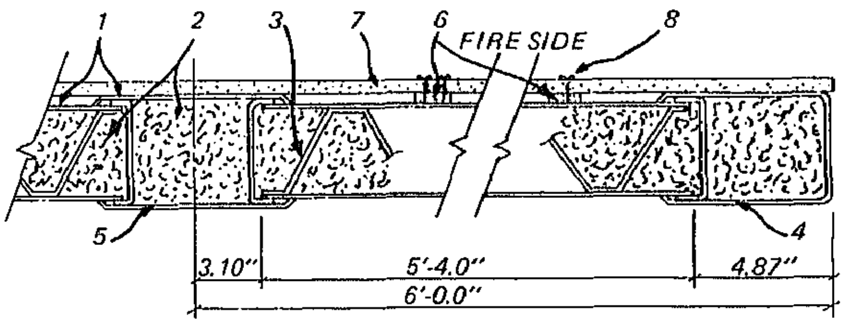
FIGURE 2.23
Vertical Section of an Intermodule Double Wall

REF W[illegible]amson, R.B. and Baron, F.M., *Structural Research Labora* 71 11, University of California, Berkeley, California, (Unpublished).

gypsum wall board installed vertically over 3/8-in asbestos mill board furring strips. The furring strips served as a seal between the gypsum board and the wall face on top and bottom of the wall (in a manner similar to that shown in Section 2.2.2.18) and at the joints of the gypsum board panels as is shown in Figure 2.23. The gypsum wall board surface, which would normally face the interior of a double wall cavity, was exposed to the fire in the test furnace. The test wall was 8 ft high by 12 ft long, and a load of 700 lb/ft was applied during the test.

Test Results:

The test wall sustained a fire exposure of 1 hr 3 min with no failure due to either temperature rise, passage of flame or load. The test was then terminated, since the desired one hour rating had been achieved.



Construction

1. 0.080-in thick glass fiber reinforced polyester laminate bonded to stiffeners with adhesive.
2. Mineral wool insulation packed into all cavities. Sodium silicate and water binder.
3. 0.050-in thick corrugated stiffeners made from same glass fiber reinforced polyester formulation as 1.
4. Wall end stud molded from same laminate as 1.
5. Straight joint molded from same laminate as 1.
6. 3/16-in asbestos mill board furring strips spaced 23 in o. c.
7. 5/8-in type X gypsum wall board with taped joints.
8. #10 x 1-in sheet metal screws spaced 12 in o. c.

FIGURE 2.24
Horizontal Section of One Leaf of an Intermodule Double Wall

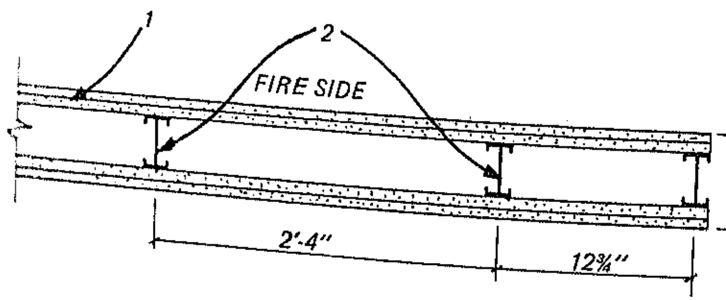
REF: Williamson, R.B., Brauer, F.B., Baron, F.M., *Structural Research Laboratory, Report No. 72-7,* University of California, Berkeley, California, June 1972 (Unpublished).

This wall assembly was composed of 2 by 4-in (nominal) alu... studs spaced 24 in o. c., with two layers of 5/8-in type X gypsum... on each side. The top and bottom plates of the partition fra... aluminum channels. The test wall assembly was 10 ft... approximately 10 ft 1 1/2 in long.

Test Results:

The fire endurance time for the partition was 2 hr 2 min. When t... terminated at that time, the temperature rises on the unexpose... not exceeded the permissible limits, nor had there been any... flame, hot gases or smoke through the wall.

Note: Subsequent to the above fire test, an identical wall assembly was... loadbearing wall with a superimposed load of 440 lb/ft. This wall successfull... a fire endurance of 1 hr 2 min, the hose stream test and double the initial ap... hr after the hose stream test.



Construction

1. Two layers of 5/8-in type X gypsum wall board each side, with joints... 24 in o.c. between the interior layers on opposite sides of the studs and... the first and second layers on each side. All joints occurred over studs. F... attached to framing with 1-in type S-12 self-drilling screws spaced 12... second layer with 1 5/8-in type S-12 self-drilling screws spaced 12 in o. c.... joints were reinforced with joint tape and covered with joint compound.... screws heads were covered with joint compound.
2. 2 by 4-in (nominal) extruded aluminum studs with 0.055-in truss web, 2... except at each end of test wall panel as shown. Aluminum channel plates... to studs at top and bottom of assembly.

FIGURE 2.25
Horizontal Section of One Leaf of an Intermodule Double Wall

IRE ENDURANCE: OOF/CEILING, LOOR/CEILING, AN LOOR ASSEMBLIE

honeycomb and glass fiber reinforced polyester resin panels were among the unconventional materials proposed for use.

of the lack of valid test data on the properties of such proposed entional systems, considerable fire endurance testing was required to obtain the information.

st Methods

was generally performed in accordance with the requirements of ASTM E 119 rs and roofs. The test specimen is installed in a horizontal position as the roof furnace; a load is applied, and the temperature of the furnace is raised in nce with the standard ASTM E 119 time-temperature curve. The specimen is l to the fire from its under side, as is shown in Figure 3.2.

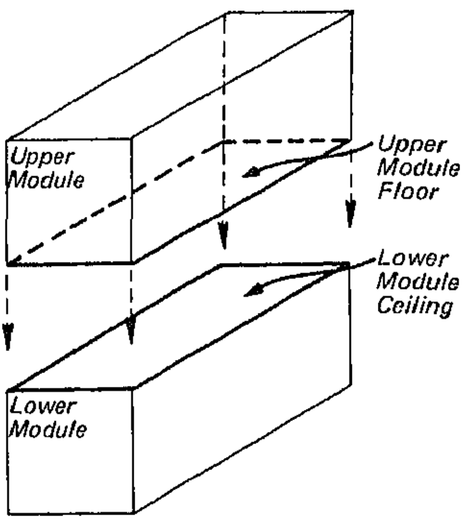


FIGURE 3.1
Double Floor/Ceiling Construction

a typical value of 40 lb/ft^2 most commonly bein
systems ranged from 18.5 to 30 lb/ft^2 and vari
specified for the geographical areas where the sy
generally applied either through the use of hy
application of dead weights such as cinder blocks
of the test assembly.

Floor systems were tested with the floor cover
common practice. It was, however, in k
BREAKTHROUGH practice of testing complete sy

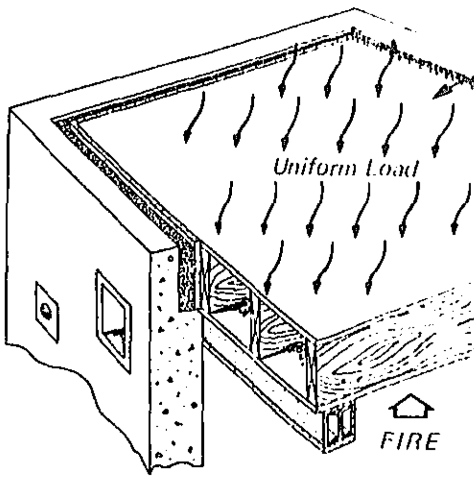


FIGURE 3.2
Furnace Test Asse

REF: *Standard Methods of Fire Tests of Buil*
119, 1971, ASTM Book of Standards, P
Materials, Philadelphia, Pennsylvania 191

inside of the parapet stub walls, sloping 3/16 in per foot, or 3 inches in t
16 ft length of the parapet wall. A sheet vinyl roofing material was bond
to the sheathing and continued up the inside of the parapet walls.

Three tests were conducted on three separate test assemblies, t
construction for Test 1 being as described above. Each assembly measur
11 ft 9 1/2 in by 17 ft 5 in.

The test specimen for Test 2 was identical to that for Test 1 except that t
ceiling assembly was insulated with *two* layers of 3 1/2-in thick glass fib
batts instead of one, and a 1/4-in bead of adhesive was applied to each jo
before the wall board was nailed.

The test specimen for Test 3 was identical to that for Test 2 except that
additional layer of 1/2-in type X gypsum board was added to the ceili
surface. The first layer was applied with the long dimension parallel to t
joists, as in Test 2. The second layer of wall board was applied parallel to t
joists with the joints offset 16 in and attached with 7d cement-coated na
spaced 6 in o. c. at the joints and spaced 12 in o. c. at intermediate jois
Type G, 1 1/4-in drywall screws were placed 2 in back from the joints a
driven into the first layer at 12 in o. c. on either side of the joints. The n
heads and wall board joints were finished with joint compound.

Before each test, a superimposed load of 30 lb/ft^2 was applied to the ro
system.

systems ranged from 18.5 to 30 lb/ft^2 and varied with the roof load requirements specified for the geographical areas where the systems were to be used. Loading was generally applied either through the use of hydraulic jacks or through the direct application of dead weights such as cinder blocks in a uniform pattern over the surface of the test assembly.

Floor systems were tested with the floor coverings installed, although this is not common practice. It was, however, in keeping with the basic Operation BREAKTHROUGH practice of testing complete systems whenever possible.

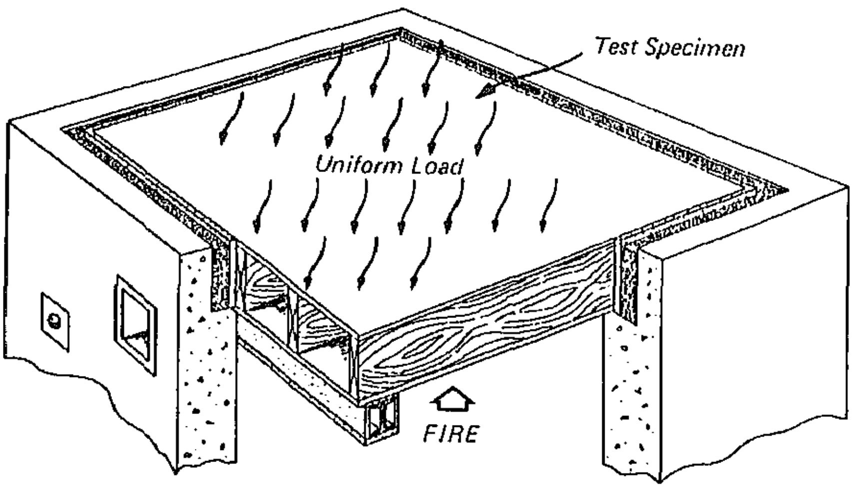


FIGURE 3.2
Furnace Test Assembly

REF: *Standard Methods of Fire Tests of Building Construction and Materials,* ASTM E 119, 1971, ASTM Book of Standards, Part 14, American Society for Testing and Materials, Philadelphia, Pennsylvania 19103.

high stub or parapet wall, constructed with 2 by 4 studs 24 in o. c. Both sides of the stub wall were sheathed with 1/2-in plywood.

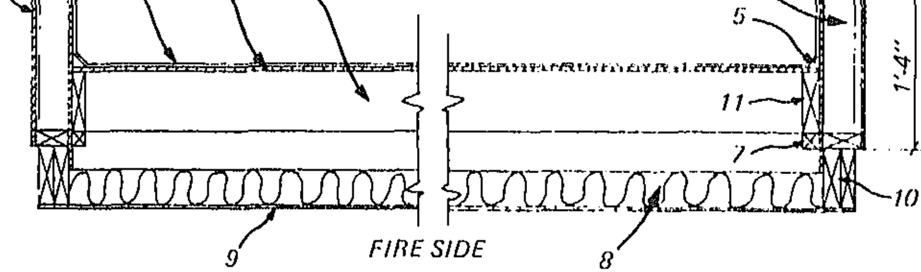
The roof assembly consisted of 2 by 6 wood joists 16 in o. c., nailed to 2 by 6 edge beams. The roof sheathing material was 1/2-in plywood. The roof assembly was supported on 2 by 2 wood ledgers glued and nailed to the inside of the parapet stub walls, sloping 3/16 in per foot, or 3 inches in the 16 ft length of the parapet wall. A sheet vinyl roofing material was bonded to the sheathing and continued up the inside of the parapet walls.

Three tests were conducted on three separate test assemblies, the construction for Test 1 being as described above. Each assembly measured 11 ft 9 1/2 in by 17 ft 5 in.

The test specimen for Test 2 was identical to that for Test 1 except that the ceiling assembly was insulated with *two* layers of 3 1/2-in thick glass fiber batts instead of one, and a 1/4-in bead of adhesive was applied to each joist before the wall board was nailed.

The test specimen for Test 3 was identical to that for Test 2 except that an additional layer of 1/2-in type X gypsum board was added to the ceiling surface. The first layer was applied with the long dimension parallel to the joists, as in Test 2. The second layer of wall board was applied parallel to the joists with the joints offset 16 in and attached with 7d cement-coated nails spaced 6 in o. c. at the joints and spaced 12 in o. c. at intermediate joists. Type G, 1 1/4-in drywall screws were placed 2 in back from the joints and driven into the first layer at 12 in o. c. on either side of the joints. The nail heads and wall board joints were finished with joint compound.

Before each test, a superimposed load of 30 lb/ft^2 was applied to the roof system.



Construction

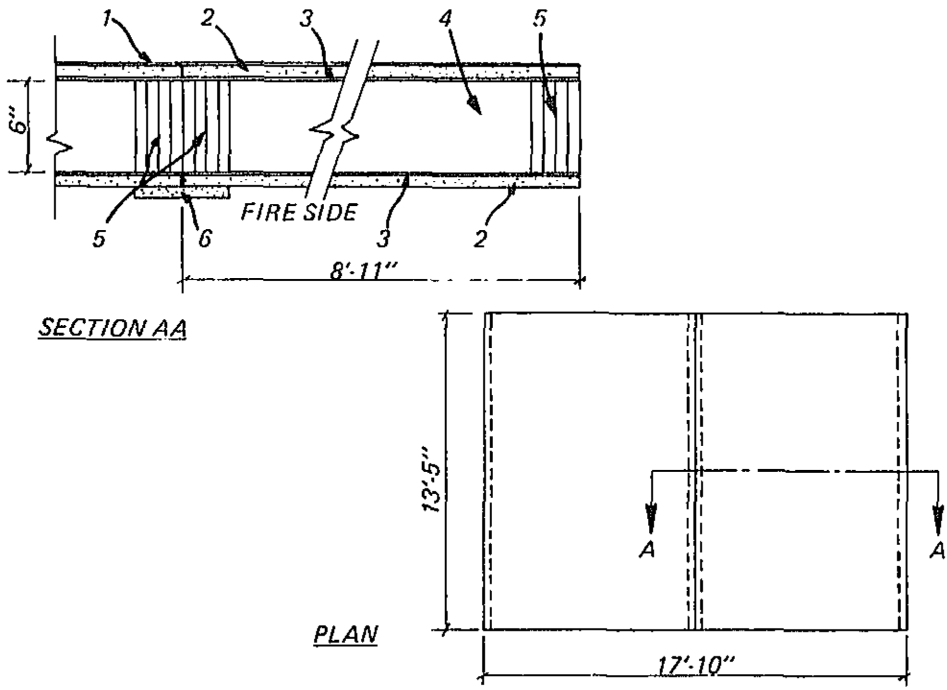
1. Vinyl roofing bonded to plywood sheathing with adhesive.
2. 1/2-in plywood sheathing attached with long dimension parallel to the joists.
3. 2 by 6 wood roof joists 16 in o. c.
4. 2 by 4 wood studs 24 in o. c. and nailed to a top and bottom plate.
5. Wood fiber cant strip.
6. 1/2-in plywood sheathing both sides of parapet stud wall.
7. 2 by 2 wood ledger-slope 3/16 in per ft.
8. 2 by 4 wood ceiling joists 16 in o. c. with 3 1/2-in thick paper faced glass fiber insulating batts between.
9. 1/2-in thick type X gypsum board applied with long dimension parallel to the joists with No. 4 ring shank nails 6 in o.c. around perimeter and 12 in o.c. at intermediate joists. Wall board joints and nail heads finished with joint compound.
10. Double 2 by 6 wood ceiling perimeter beam.
11. 2 by 6 wood roof perimeter beam.

Note: On the open end of the roof assembly, created by the 3/16-in/ft slope, an "eyebrow" consisting of 2 by 6 joists and plates with 1/2-in plywood and asphalt shingles was placed to fill the open area. The asphalt shingles were replaced by 1/2-in type X gypsum wall board for Tests 2 and 3.

FIGURE 3.3
Cross Section of Roof/Ceiling Construction

REF: *Fire Test Reports RC-168, RC-169 and RC 171,* National Gypsum Company Research Center, Buffalo, New York 14217, January and February 1972. (Unpublished)

Failure occurred at a corrected time of 37 min 13 s by flame-through at the unexposed surface through a joint in the gypsum boards. About 10 seconds later, a local load failure occurred at the same joint.



Construction

1. Weather-resistant coating of resin with chopped glass fiber and sand applied to an exterior surface of panels.
2. 5/8-in type X gypsum board bonded to resin facing on core with polyester adhesive. Joints in the boards on the two sides of a panel were staggered. Joints between gypsum boards taped and filled with plaster joint compound.
3. Woven glass fiber roving and polyester resin facings both sides of core.
4. Flame-retardant treated paper honeycomb core.
5. 3 by 6-in edge beams consisting of 4 layers of 3/4-in plywood.
6. 5-in wide strip of 5/8-in type X gypsum board covering the joint between test panels.

FIGURE 3.4
Roof/Ceiling Assembly
Test Specimen

REF: Son, B. C., *Fire Endurance Test of a Roof/Ceiling Construction of Paper Honeycomb and Gypsum Board,* NBSIR 73-167, National Bureau of Standards, Washington, D.C. 20234, January 1973. (NTIS Accession No. PB-222 298)

Flame-through at the panel joint occurred at 29 min.

REF: *Fire Test Report FC-156,* National Gypsum Company, Buffalo, New York 14217
(Unpublished)

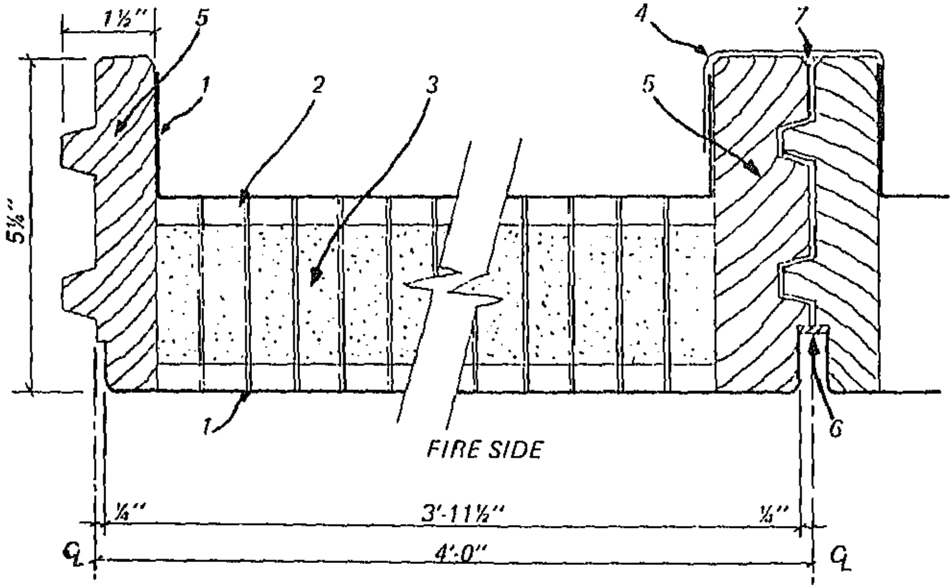
Test Results:

Flame-through at a gypsum board joint at the unexposed side occurred at 1 hr 4 min 45 s.

REF: *Fire Test Report FC-159,* National Gypsum Company Research Center, Buffalo, New York 14217 (Unpublished)

Test Results:

A maximum temperature rise of 325°F (181°C) occurred at one thermocouple on the unexposed side at 9 min 9 s.



Construction

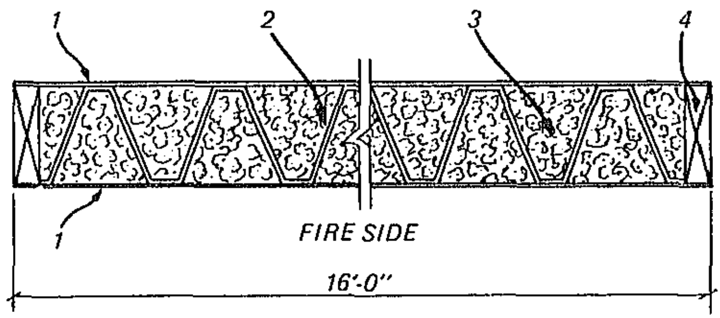
1. 26 ga sheet steel facing bonded to honeycomb core with epoxy adhesive. Steel sheets were galvanized, phosphatized and finished on exterior surfaces with a baked on silicone paint.
2. 3-in thick paper honeycomb core with 3/4-in hexagonal cores, paper impregnated with phenolic resin (11 per cent by weight).
3. 2 1/4-in thick rigid and friable polyurethane foam insulation (1.5 lb/ft^3 density) pressed into honeycomb core.
4. 26 ga galvanized sheet metal joint cap (field applied).
5. Tongue and groove wood panel edging on long ends of each panel. Short ends closed by 1 1/2 by 3-in wood edge members.
6. 1/16 by 3/8-in vinyl tape (field applied).
7. 1/4 by 1/4-in butyl tape (field applied).

FIGURE 3.5
Cross Section of
Roof/Ceiling Assembly

REF: Son, B. C., *Fire Endurance Tests of Steel Sandwich Panel Exterior Wall and Roof/Ceiling Constructions,* NBSIR 73-135, National Bureau of Standards, Washington, D.C. 20234. (NTIS Accession No. PB-221 310)

Test Results:

The test assembly could no longer sustain the applied load after 48 min of exposure to fire.



Construction

1. 0.151-in thick structural glass fiber reinforced polyester resin composite bonded to stiffeners with modified polyester adhesive.
2. 0.05-in thick structural glass fiber reinforced polyester resin composite stiffeners coated with intumescent paint except on bonding surfaces.
3. Mineral wool insulation with 10 percent sodium silicate and water binder.
4. 2 by 6 kiln dried Douglas Fir rim joists with external surface coated with intumescent paint. Bonded to composite skins with modified epoxy adhesive.
5. Load span 11 ft 7 1/2 in.

FIGURE 3.6
Cross Section of
Roof/Ceiling Assembly

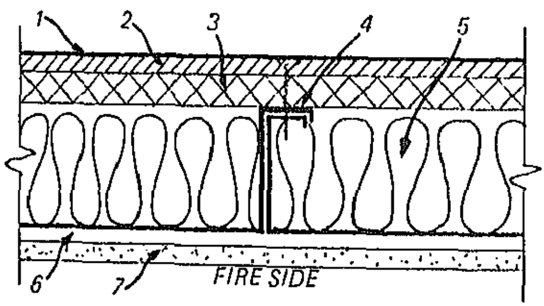
REF: *Report No. 5067, Standard ASTM Fire Endurance Test on a Roof and Ceiling Assembly,* Building Research Laboratory, Engineering Experiment Station, Ohio State University, Columbus, Ohio 43210, September 1971. (Unpublished)

board attached to steel furring channels 24 in o. c. perpendicular to the steel pans.

The 12-ft 5-in by 16-ft test specimen was loaded so as to produce the equivalent maximum bending moment at mid-span resulting from a uniform load of 30 lb/ft^2 over an 11-ft 11-in clear span.

Test Results:

After 42 min of exposure to fire, the hydraulic loading jacks in one section had reached their limits of extension and were no longer able to apply load due to the deflection of the test specimen. The test, however, was continued for another 5 min. When terminated at 47 min, the system was still holding, although sagging more than 8-in. No flame-through was observed nor were any excessive temperature rises on the unexposed surface recorded.



Construction

1. Silicone rubber waterproofing compound.
2. 1/2-in exterior grade plywood attached to rigid insulation and steel decking with sheet metal screws.
3. 1-in rigid glass fiber insulation.
4. 20 ga galvanized sheet steel interlocking pans, 4 in deep by 16 in wide by 12 ft 5 in long.
5. 3 1/2-in thick unfaced glass fiber insulating batts.
6. Steel furring channels 24 in o. c. perpendicular to span.
7. 1/2-in type X gypsum board.

FIGURE 3.7
Cross Section of
Roof/Ceiling Assembly

REF: *Report of a Standard ASTM Fire Endurance Test of a Limited Load Bearing Roof and Ceiling Assembly*, Building Research Laboratory, Engineering Experiment Station, Ohio State University, Columbus, Ohio 43210, Project 5234, March 1972. (Unpublished)

carpet over a pad. The remaining half was covered with 1/16-in vinyl asbestos tiles (12 in square) bonded to the plywood with adhesive. One layer of 1/2-in type SF-3 gypsum board was attached directly to the bottom flanges of the joists.

The ceiling consisted of 1/2-in type SF-3 gypsum board attached to 7/16-in deep steel furring channels spaced 12 in o. c. and running perpendicular to the joist span.

The 12-ft 5-in by 16-ft 6-in assembly was loaded uniformly with 45 lb/ft^2 before the start of the fire test.

Test Results:

At 52 min, flame-through occurred on the half of the exposed floor surface covered with vinyl floor tile, followed by structural collapse of the test assembly at 52 min 45 s.

REF: *Report on Fire Endurance Test of Floor and Ceiling Construction,* U. L. File R6946-1, Underwriters Laboratories, Inc., Northbrook, Illinois, February 1972. (Unpublished)

Construction

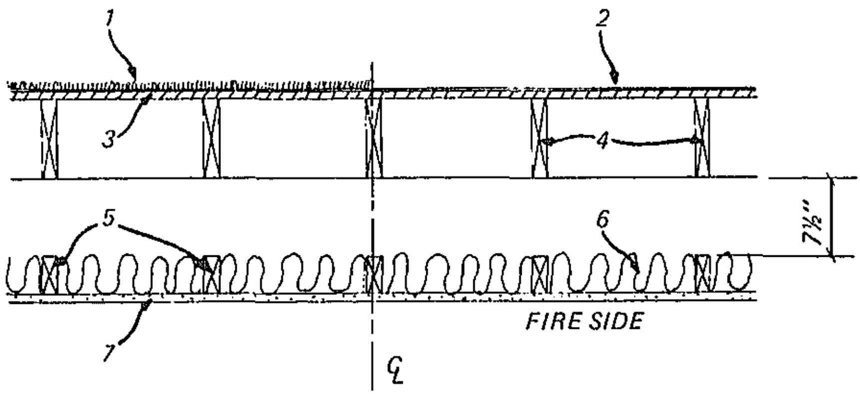
1. Shag carpet and hair jute pad, 12 ft by 8 ft 6 in, installed on half of the as Carpet identified as complying with FHA Bulletin No. UM44B (Shag Rug).
2. 1/16-in thick vinyl asbestos floor tile installed with water emulsion fl adhesive on the other half of the assembly.
3. 3/4-in T and G plywood underlayment, PS 1-66 interior grade with exter 47 7/16 by 96-in. Attached to upper flanges of the joists with #12 self drilli tapping steel screws spaced 12 in o. c. Plywood panels placed with long dim perpendicular to the joists. Butt ends of the plywood panels glued with st adhesive. End joints were staggered 4 ft o. c. and located over joists.
4. 1 3/4 by 7 1/2-in 18 ga galvanized steel floor joists 24 in o. c. (12 ft 5 i Lower flange of each joist end attached to the flange of a boundary st beam with a #10 machine screw in a 1/2-in slotted hole. Ends of ea stiffened with 3/4-in by 1 3/4-in by 16 ga (0.06-in) galvanized steel sections placed with the folded leg inserted over the web of each joist.
5. 1/2-in type SF-3 gypsum board attached to lower joist flanges (ceiling sid 0.115-in diameter, 1-in long type S-12 bugle head self drilling, self tappi screws at 12 in o. c. Gypsum board panels placed with long din perpendicular to the joists. End joints staggered 4 ft between adjacent ro joints were in line.
6. Second layer of 1/2-in type SF-3 gypsum board was attached to furring c with 0.115-in diameter type S-12 bugle head self drilling, self tapping sc 12 in. o. c. Long dimension installed perpendicular to first layer. En staggered a minimum of 12 in from side joints of first layer. Joint co applied over all screw heads and along the gypsum board joints in the e surface followed by perforated joint tape along all the joints and a second joint compound.
7. Resilient furring channels, 7/16-in deep, 28 ga (.021-in) galvanized steel, 12 in o. c. Attached to bugle head screws used to attach gypsum board. channels perpendicular to joists.

FIGURE 3.8
Cross Section of
Floor/Ceiling Assembly

A uniform floor load of 40 lb/ft^2 was applied to the 10-ft 10 1/2-in by 17-ft 5-in test assembly during the test.

Test Results:

Flame-through on the unexposed side occurred at 45 min 30 s.



Construction

1. Nylon shag carpet with foam backing on approximately one half of the floor area.
2. 1/8-in vinyl asbestos floor tile adhered to plywood subfloor on remainder of floor area (8 ft 8 in by 11 ft 9 1/2 in).
3. 5/8-in plywood subfloor attached to joists with 1/4-in bead of structural adhesive and 6d nails spaced 6 in o. c. at the joints and 12 in o. c. at intermediate joists. Long dimension parallel to joists.
4. 2 by 8 wood floor joists 16 in o. c. nailed to perimeter joists.
5. 2 by 4 wood ceiling joists 16 in o. c. nailed to perimeter joists.
6. 3 1/2-in thick, paper faced, glass fiber insulating batts.
7. 5/8-in type X gypsum board applied with long dimension parallel to joists. Attached to joists with 1/4-in bead of structural adhesive and No. 4 ring shank nails spaced 6 in o. c. at the joints and 12 in o. c. at intermediate joists. Wall board joints and nail heads finished with joint compound.

FIGURE 3.9
Cross Section of
Floor/Ceiling Assembly

REF: *Fire Test Report FC-170,* National Gypsum Company Research Center, Buffalo, New York 14217, February 1972. (Unpublished)

paint. One layer of 2-in thick glass fiber blanket insulation was laid over ceiling joists.

Three 11-ft 8-in by 17-ft 4-in specimens were tested, the constructio Test 1 being as described above. A load of 40 lb/ft^2 over the 11-ft 8-in was applied to each of the specimens.

The test specimen for Text 2 was basically the same as that for T except that the ceiling membrane consisted of two layers of 1/2-in ty gypsum board, the exposed surface of which was left unpainted.

The test specimen assembly for Test 3 differed slightly in overall size those used in Tests 1 and 2. It was 11 ft 9 in by 17 ft 11 in. The c membrane was a single layer of 5/8-in type X gypsum board, a continuous 3-in wide, 24 ga steel bracing strap was welded to the tops c ceiling joists at midspan.

Test Results:

Test 1*: At 50 min flame-through occurred on the carpeted half c unexposed floor surface.

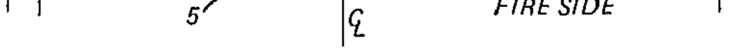
Test 2**: The test was terminated at 1 hr 10 min 30 s, when stru failure appeared imminent.

Test 3***: Failure occurred at a corrected time of 30 mi flame-through to the unexposed floor surface.

*REF: Fire Test Report FC-166, National Gypsum Company Research C Buffalo, New York 14217, December 1971. (Unpublished)

**REF: Fire Test Report FC-167, National Gypsum Company Research C Buffalo, New York 14217, January 1972. (Unpublished)

***REF: Son, B. C., *Fire Endurance Tests of Plywood on Steel Joist Floor Asse With and Without Ceilings,* NBSIR 73-141, National Bureau of Star Washington, D. C. 20234, March 1973. (NTIS Accession No. PB-220 43(



Construction

1. 3/4-in tongue and groove plywood subflooring attached to joists with special drywall screws spaced 8 in o. c. along the edges and 12 in o. c. at intermediate joists. Tongue and groove edges bonded with neoprene structural adhesive. Plywood laid with long edges perpendicular to joists for Tests 1 and 2. Attached with 1 1/8-in long hi-lo bugle head screws 12 in o. c. for Test 3.
2. 6 by 1 3/4-in 18 ga galvanized cold-rolled steel "C" joists, 24 in o. c., spanning 140 in. Joists end-welded to cold rolled steel "H" section boundary members.
3. 2-in thick R-6 glass fiber insulating blankets laid over ceiling joists.
4. 3 by 1 3/4-in 18 ga galvanized cold-rolled steel "C" joists, 24 in o. c., plug welded to "C" section channel boundary members on each flange.
5. For Test 1: 5/8-in type C gypsum board over 3/8-in plywood. Plywood screwed with long edges perpendicular to joists with 1-in type S-12 bugle head screws 12 in o. c. Gypsum board screwed with 1 7/8-in type S-12 bugle head screws, 12 in o. c. (staggered with screws in plywood). Long edges were parallel to joists and joints finished with tapeless joint compound. Ceiling surface painted with one coat of latex paint.
   Test 2: 2 layers 1/2-in type C gypsum board. First layer applied with long edge perpendicular to joists and attached with 1-in type S-12 screws 12 in o. c. Second layer applied with long edge parallel to joists and attached with 1 5/8-in type S-12 screws spaced 12 in o. c. Joints finished with tapeless joint compound. No paint applied. Joints between the face boards reinforced by 1 1/2-in type G bugle head screws at 12 in o. c., staggered 6 in from 1 5/8 in S-12 screws.
   Test 3: 1 layer 5/8-in type X gypsum board attached with 1-in type S-12 bugle head screws spaced 6 in o. c. along the edges and 12 in o. c. at intermediate joists.
6. 3/8-in nylon pile carpeting on 1/8-in jute backing, laid over 1/4-in rubberized hair pad.
7. Resilient sheet vinyl flooring bonded to floor deck with latex adhesive.

Note: Stub walls erected around the perimeter of the floor and ceiling assemblies used to maintain the assemblies in position.

FIGURE 3.10
Cross Section of
Floor/Ceiling Assembly

Note: The effects of different floor coverings over such construction w
in a series of small-scale fire endurance tests described in Section 4.5 of t

Test Results:

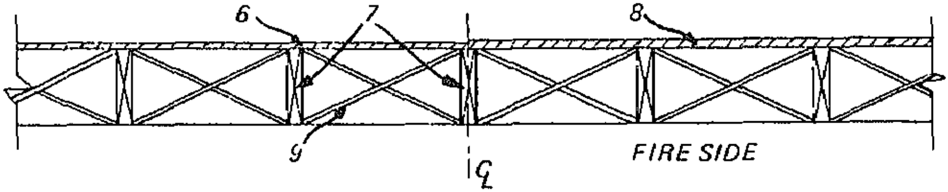
Specimen L-1: A load of 63.7 lb/ft^2 was applied to the fl
before the start of the test. This load produced the design stress

At 11 min 38 s, the specimen indicated the inability to sustai
load, and at 13 min 30 s, flame-through occurred at a j
plywood sheets on the bare floor. When the test was terminat
no excessive temperature rises on the upper surface had been re

Specimen L-2: Specimen L-2 was loaded with 21 lb/ft^2 before
This load was representative of the live loads anticipated in actu

Failure by excessive temperature rise occurred at 9 min fo
plywood floor section and at 10 min for the section with 5/
flooring.

REF: Son, B. C., *Fire Endurance Tests of Unprotected Wood Floor C*
Single-Family Residences, NBSIR 73-263, National Bureau
Washington, D.C. 20234, July 1973. (NTIS Accession No. PB-225 2



SPECIMEN L-2

Construction

1. 1/2-in grade A-C plywood underlayment nailed with 6d coated nails spaced 12 in o. c. Gap of 1/16 in at plywood joints. Joints staggered between underlayment and subfloor layers.
2. 1/2-in grade C-D plywood subflooring nailed with 8d coated nails spaced 6 in o. c. along the edges and 10 in o. c. at intermediate joists. Gap of 1/16 in at plywood joints.
3. 2 by 10-in construction grade Douglas Fir joists, 16 in o.c., with a span of 13 ft 6 in.
4. Nylon 501 carpet (weight 66.7 oz/yd^2) over hair pad covered one half of specimen. Remainder was bare and had no finish floor.
5. 2 by 10 solid bridging between joists, 5 ft o. c., staggered for direct nailing.
6. 1/2-in interior grade A-C plywood with square edge joints protected by 2 by 3 blocking placed in line for toe nailing. Nailed with 8d common nails spaced 10 in o. c.
7. 2 by 8 construction grade Douglas Fir joists, 16 in o. c., with a span of 13 ft 6 in.
8. 5/8-in tongue and groove plywood, underlayment grade. Nailed with 8d common nails spaced 10 in o. c.
9. One row adjustable metal bridging at midspan.

FIGURE 3.11
Cross Sections of Floor Assemblies

assembly used for test No. 3 in Section 3.2.2.3 (see Figure 3.1(
equivalent to 51.4 lb/ft^2 was applied to the floor specimen.

Test Result:

Failure occurred at 3 min 15 s when flame-through occurre
unexposed surface, followed by collapse of the entire assembly at 3

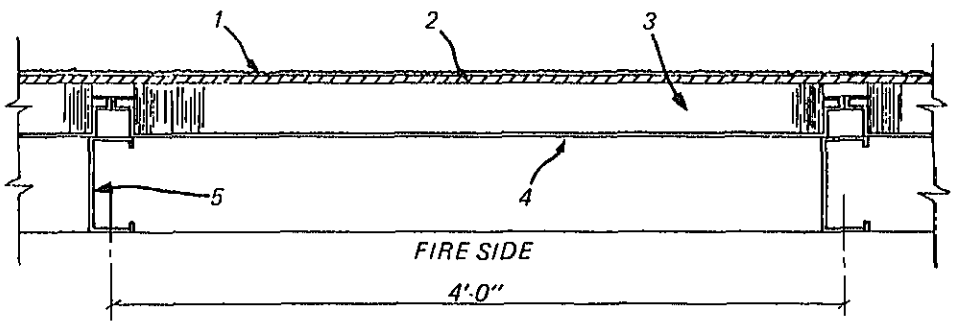
REF: Shoub, H. and Son, B. C., *Fire Endurance Tests of Plywood on Steel J
Assemblies, With and Without Ceiling, NBSIR 73-141, National
Standards, Washington, D.C. 20234, March 1973. (NTIS Accession N
430)

exterior glue) and a bottom surface of 26 ga galvanized sheet steel.

All panels were 10 ft 7 1/4 in long. Three 4-ft wide panels were placed in the middle of the floor framing, with one 2-ft 11 1/2-in wide panel at each end, for a total of 5 panels. Joints between panels were sealed with 3/8-in wide butyl sealant strips. Carpeting was bonded to the plywood with a commerical natural latex releasable adhesive. A 40 lb/ft^2 load was applied to the floor assembly during the test.

Test Results:

Failure by flame-through occurred at a joint between two sandwich panels at 8 min 45 s, followed by structural failure at 9 min.



Construction

1. Carpeting bonded with natural latex releasable adhesive.
2. 3/8-in C-D plugged interior grade plywood (with exterior glue). Gaps between plywood top sheets did not exceed 1/16 in.
3. 3-in thick paper honeycomb core.
4. 26 ga galvanized sheet steel bent up on long sides of panel to cover bottom 1 1/2-in of paper core and shaped to contain a 5/16 by 5/16-in boss to compensate for a 5/16-in setback in the paper core from the joint edge.
5. 6 by 3-in 14 ga steel "C" joists, 48 in o. c., welded to perimeter frame. Panel joints located over joists.

FIGURE 3.12
Cross Section of Floor Assembly

REF: Son, B. C., *Fire Endurance Test of a Steel Sandwich Panel Floor Construction,* NBSIR 73-164, National Bureau of Standards, Washington, D.C. 20234, April 1973. (NTIS Accession No. PB-221 642)

FIRE ENDURANCE: OTHER TESTS

consuming large scale testing required.

4.1 Fire Endurance of a Wall Assembly Exposed on Both Sides

Wall structures inside a dwelling unit can be exposed to fire on both sides, since the fir can travel from one room to another through open doorways and corridors.

This test was performed to experimentally determine any correlation between the fir resistance of a wall when it is exposed to flames on both sides and the fire resistance o a similar wall assembly when it is exposed to flames on one side, as is the case in th standard ASTM E 119 test procedure for walls.

A typical wood frame intermodular double wall assembly with 5/8-in fire resistan gypsum wall board on the module interior wall surfaces and 1/2-in plywood on th module exterior surfaces was used for the test (see Figure 4.1 for construction details)

Since ASTM E 119 wall test furnaces do not have the capability of exposing wal assemblies to fire on both sides, the wall test assembly was mounted vertically in floor test furnace. Two rows of burners on either side of the wall assembly wer removed from the furnace to accommodate the partition. The top of the furnace wa closed off by a gypsum wall board ceiling, which protected the top surface of the wa assembly. A concrete floor assembly, including bar joists, was placed over the ceiling

The test was conducted without a superimposed load, and the furnace temperature were raised in accordance with the standard time-temperature curve of ASTM E 11 One side of the double wall partition was instrumented with 42 thermocouple Thirty-six of these were installed in nine locations, with one on each surface of th gypsum wall board, one on the air space side of the plywood sheathing and the fourt thermocouple located in the air space between the wall elements. The remaining si thermocouples were placed on the wood studs in the wall cavity. Temperatures in th furnace were controlled by 16 thermocouples set near the wall assembly at a height o 4 ft.

The test was terminated after a fire exposure of 54 min, when it became obvious tha the plywood between the two walls was burning. A similar wall assembly (see Sectio 2.2.2.4) had a fire endurance rating of 75 min when exposed to fire on one side.

6. 2 by 4 wood plates attached to studs with two 12d nails per
bottom.

FIGURE 4.1
Horizontal Section of
Intermodular Double Wall

REF: National Gypsum Company, *Fire Test FC-157. (Unpublished)*

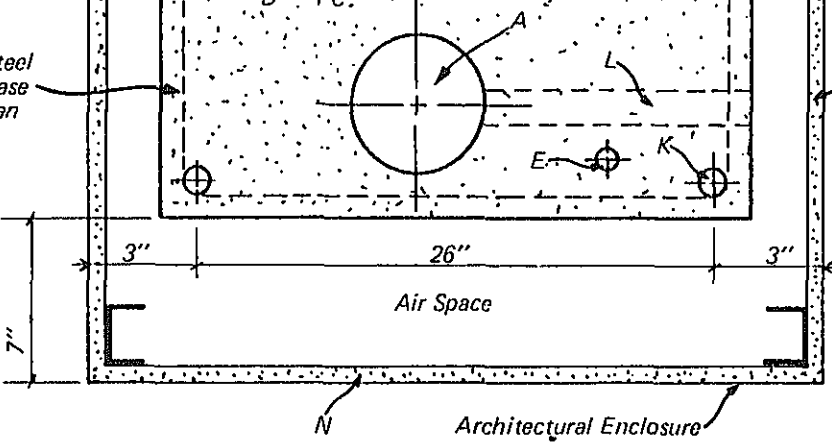
4.2 Fire Endurance of a Mechanical/Electrical Core Assembly

The use of prefabricated mechanical/electrical cores in multi-
construction was investigated as a potential path for the spread of fires.

This test was conducted to determine the fire endurance
mechanical/electrical core assembly intended for use by one of
BREAKTHROUGH Housing System Producers. It is believed to be
endurance test of a complete prefabricated service core in the Unite
vertically adjacent levels of a mechanical/electrical core designed to
floors in an apartment building were used for the test. The core assem
inside an architectural enclosure which simulated the walls surroundi
actual construction.

The mechanical/electrical core assembly contained copper water pipes,
sheet metal kitchen and bathroom exhaust ducts and steel electrical jun
conduit, embedded in loose foamed urea formaldehyde insulation with
paper jacket.

The core was placed inside an architectural enclosure constructed from
board on two sides and 5/8-in type X gypsum wall board on the othe
enclosure was framed with C-shaped light gauge steel studs using 1
Phillips-head self-tapping drywall screws on 12-in centers. Details of th
are shown in Figure 4.2 a.



<u>LEGEND</u>

A. *6″ Diam. Main Sanitary Stack, PVC*
B. *5″x12″x16″ Electric Junction Box 14 ga Enamel Steel*
C. *1 1/2″ Diam. Copper Pipe, Domestic Hot Water, Type M*
D. *1 1/2″ Diam. Copper Pipe, Domestic Recirculation Hot Water, Type M*
E. *1/2″ Diam. Copper Pipe, Domestic Recirculation Hot Water, Type M*
F. *10″x6″ Kitchen Exhaust Duct, 22 ga Galvanized Steel*
G. *10″x4″ Bathroom Exhaust Duct, 22ga Galvanized Steel*
H. *2 1/2″ Diam. Electrical Conduit Galvanized Electrical Metallic Tubing*
I. *1″ Diam. Telephone Conduit, Galvanized E.M.T.*
J. *1″Diam. Intercom and Television Conduit, Galvanized E.M.T.*
K. *1″ opening for Electrical Cables (one in each corner)*
L. *1 1/2″ Diam. Sink Connection Pipe, P.V.C.*
M. *5/8″ Type X Gypsum Board*
N. *3/4″ Particle Board*
O. *Urea-Formaldehyde Foam Core*

FIGURE 4.2a
Construction Details of
Core Assembly

assembly shown in Figure 4.2 b consisted of the lower core unit, which was d in the NBS floor test furnace, a 6 1/2-in thick concrete slab, 6 ft square, epresented the floor in the building and served as part of the furnace closure, upper core unit which was mounted outside the test furnace. The upper core a lightweight concrete base, cast into an integral 16 ga sheet metal pan, which osely into a 2-ft by 2-ft hole in the center of the concrete floor. An asbestos s fiber caulking compound was used to seal the joint between the concrete base pan closure.

concrete slab not enough to ignite cotton waste.

2. Transmission of heat through the architectural enclo concrete slab that raises the average temperature mo (139°C) or 325°F (181°C) at one point.

The fire endurance of the test assembly was considered to be 35 m penetrated to the top of the upper level of the core.

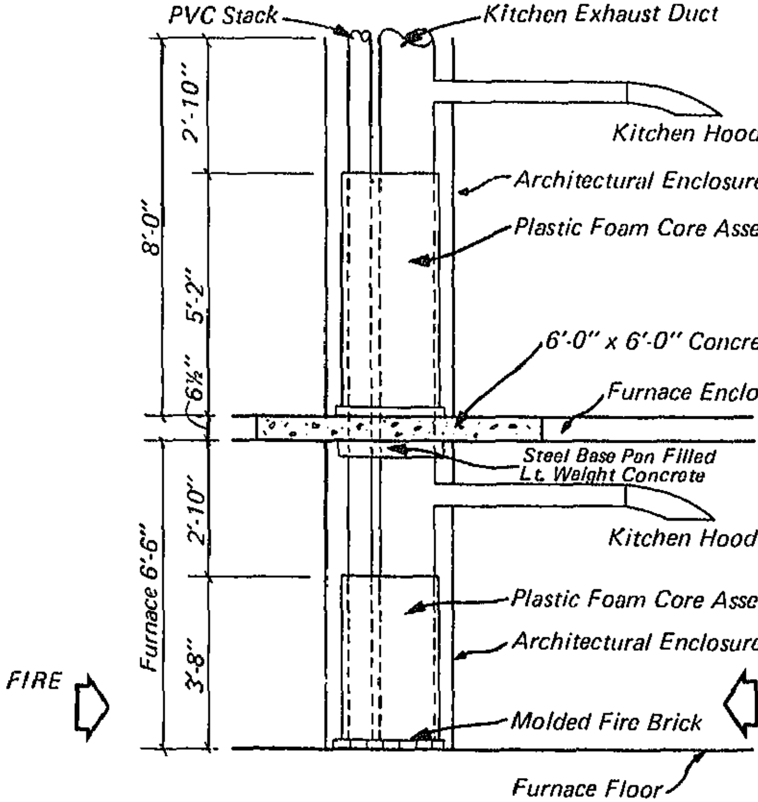


FIGURE 4.2b
Test Specimen
Mounted in Furnace

REF: Son, B.C., *Fire Endurance Test of Mechanical/Electrical Core A Multifamily Housing,* NBS Report 10415, National Bure Washington, D. C. 20234. (NTIS Accession No. PB-217 362)

ound all sides of the column, leaving an overall column length of 10 ft 8 in
ng the two 3/16-in bearing plates). Each bearing plate had four 1/2-in diameter
es located in the corners of the plate 1 in from each edge. The measured weight
olumn assembly was 120 lb.

s used to attach the gypsum board to the test column consisted of 1-in self
bugle head metal screws on the gypsum board underlayer and 2 1/4-in
ing Phillips recessed flat head metal screws on the face layers. Both were
pproximately at 16-in centers along the center line of each side of the column
. The corner reinforcement (ECONO standard dur-a-bead) was crimped to
nto the gypsum board.

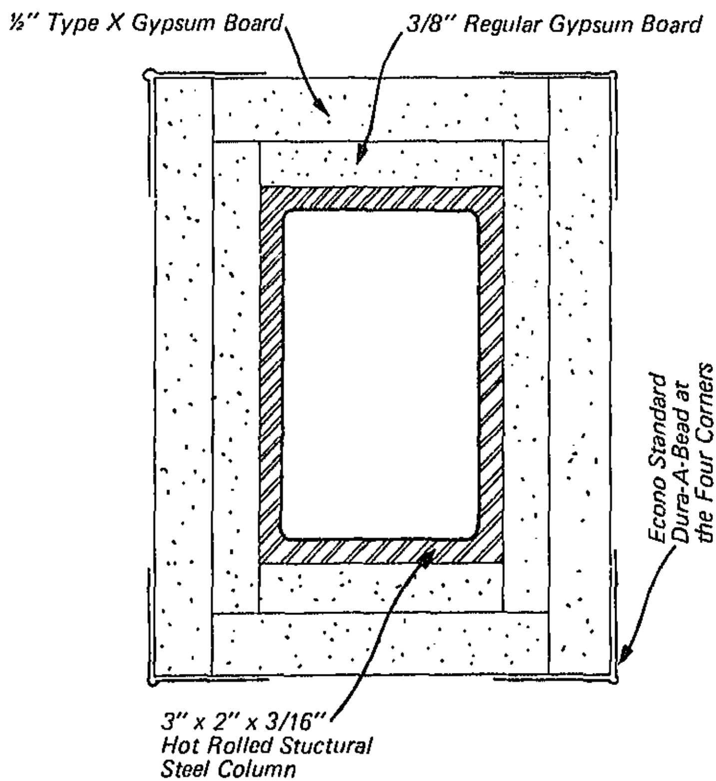


FIGURE 4.3a
Horizontal Section of
Column Assembly

concrete slab not enough to ignite cotton waste.

2. Transmission of heat through the architectural enclos concrete slab that raises the average temperature mo (139°C) or 325°F (181°C) at one point.

The fire endurance of the test assembly was considered to be 35 mi penetrated to the top of the upper level of the core.

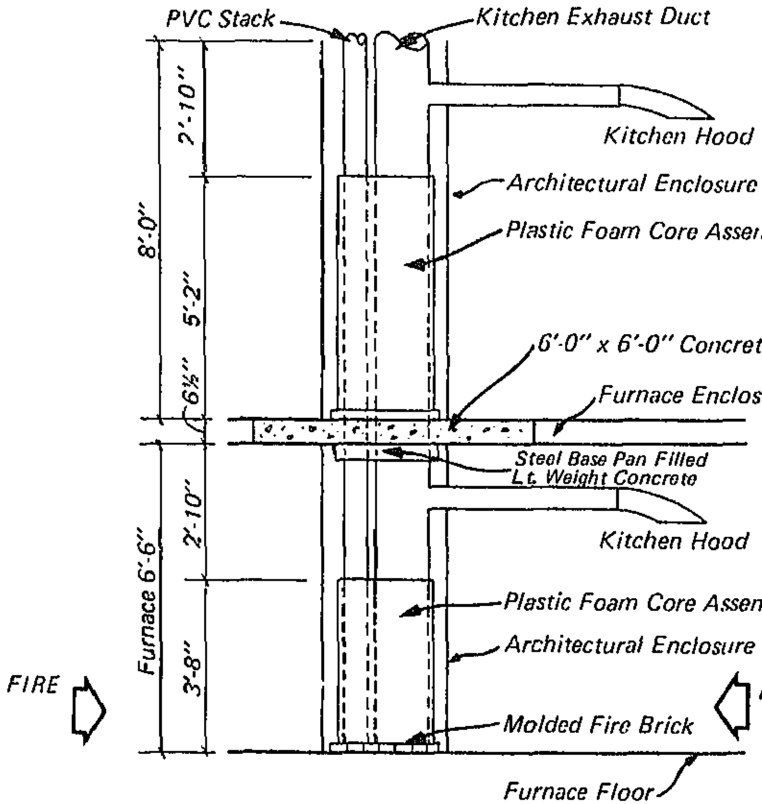


FIGURE 4.2b
Test Specimen
Mounted in Furnace

REF: Son, B.C., *Fire Endurance Test of Mechanical/Electrical Core As Multifamily Housing,* NBS Report 10415, National Burea Washington, D. C. 20234. (NTIS Accession No. PB-217 362)

ound all sides of the column, leaving an overall column length of 10 ft 8 in ng the two 3/16-in bearing plates). Each bearing plate had four 1/2-in diameter es located in the corners of the plate 1 in from each edge. The measured weight olumn assembly was 120 lb.

s used to attach the gypsum board to the test column consisted of 1-in self bugle head metal screws on the gypsum board underlayer and 2 1/4-in ing Phillips recessed flat head metal screws on the face layers. Both were approximately at 16-in centers along the center line of each side of the column y. The corner reinforcement (ECONO standard dur-a-bead) was crimped to nto the gypsum board.

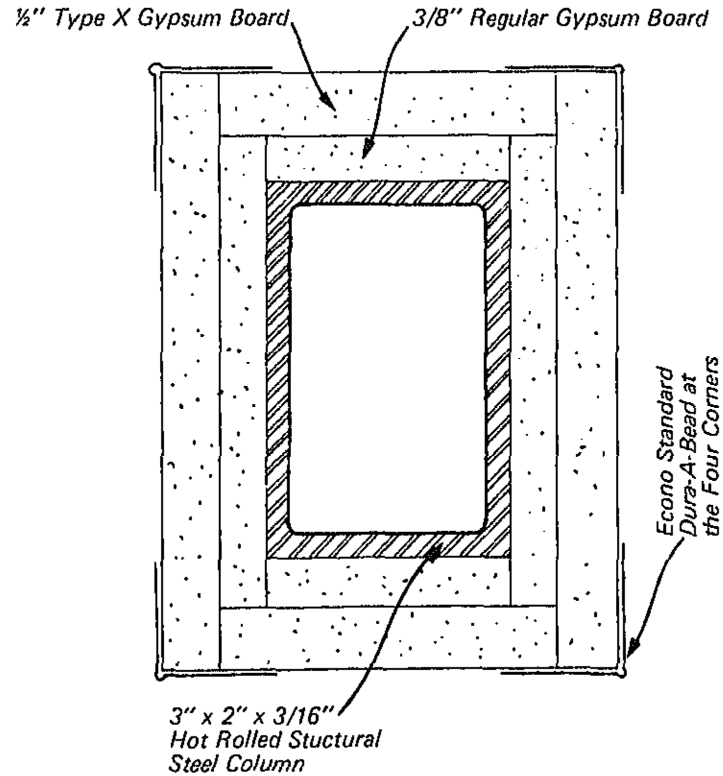


FIGURE 4.3a
Horizontal Section of Column Assembly

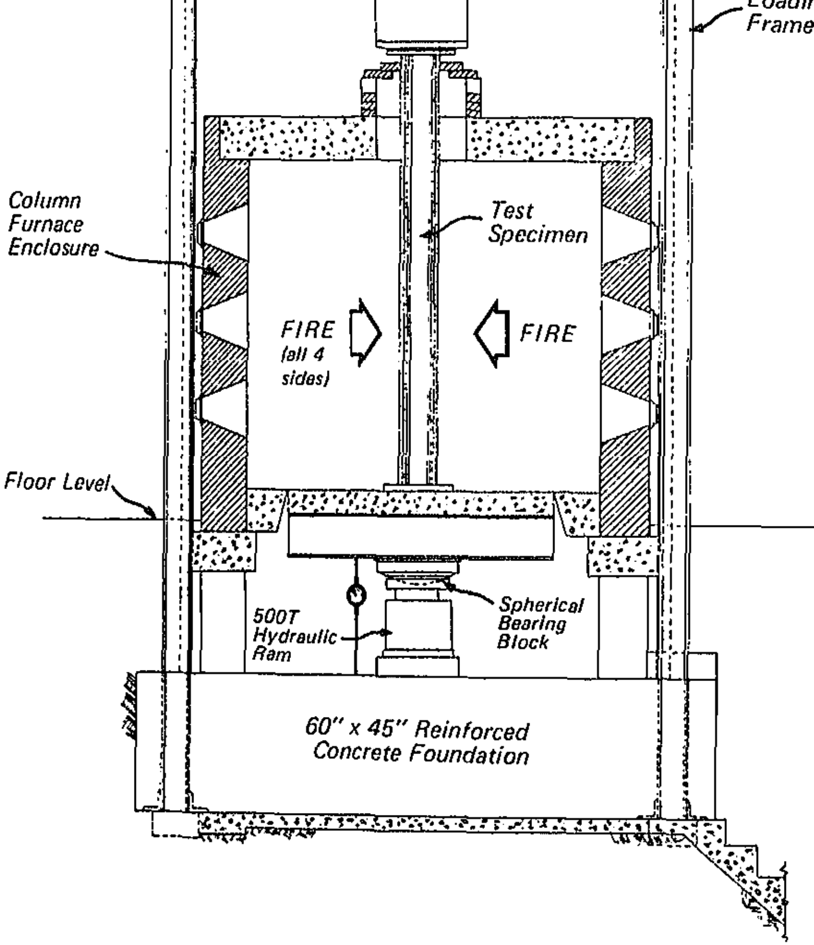


FIGURE 4.3b
Schematic of Column Fire Test Furnace Set-Up

REF: Son, B. C., *Fire Endurance Test on a Steel Tubular Column Prote* *Gypsum Board*, NBSIR 73-165, National Bureau of Standards, Washing 20234, (NTIS Accession No. PB-221 474).

case of the wood joists, it was felt that a layer of gypsum board would provide a
evel of protection, so a portion of the wood joist test assembly was protected by
gypsum board.

.4.1 Steel Stud Test

hree cold-formed 18 ga channel steel studs (C-3 by 1 3/4 in) were assembled in a orizontal position between two layers of gypsum board on the unexposed side nd an asbestos mill board on the fire side for the steel stud test. One stud was eft bare: the second was painted with one coat of intumescent paint, and the hird stud was painted with two coats of intumescent paint. In Figure 4.4.a, howing the test assembly, these are marked as B, A and C, respectively. Each oat of the modified vinyl phenolic resin intumescent paint used had a dry film hickness of 6 to 8 mils. Each stud was instrumented with two groups of three hermocouples; one located on the fire side flange, one on the web, and one on he unexposed side flange.

he assembly was then mounted as the roof of a 2 by 2-ft slab furnace, and the emperature of the furnace was raised in accordance with the standard ASTM E 19 time-temperature curve.

y analyzing the temperatures measured on the steel studs and the yield strengths ssociated with them, it was concluded that two coats of the intumescent paint sed provided no more than three minutes of additional fire endurance rotection, and that the paint would be of little value in protecting the steel.

.4.2 Wood Joist Test

n assembly consisting of three 2 by 10 wood joists was constructed for the vood joist test. As is shown in Figure 4.4.b, the joists were placed next to each ther, with the 10-in side flat, and separated by 5/8-in type X gypsum board pacers. The bottom surface of the first joist was bare; the second joist was rotected with one layer of intumescent paint 7 to 8 mils thick; the third was rotected with one layer of 5/8-in type X gypsum board. The unexposed side of he specimen was also covered with the same type of gypsum board.

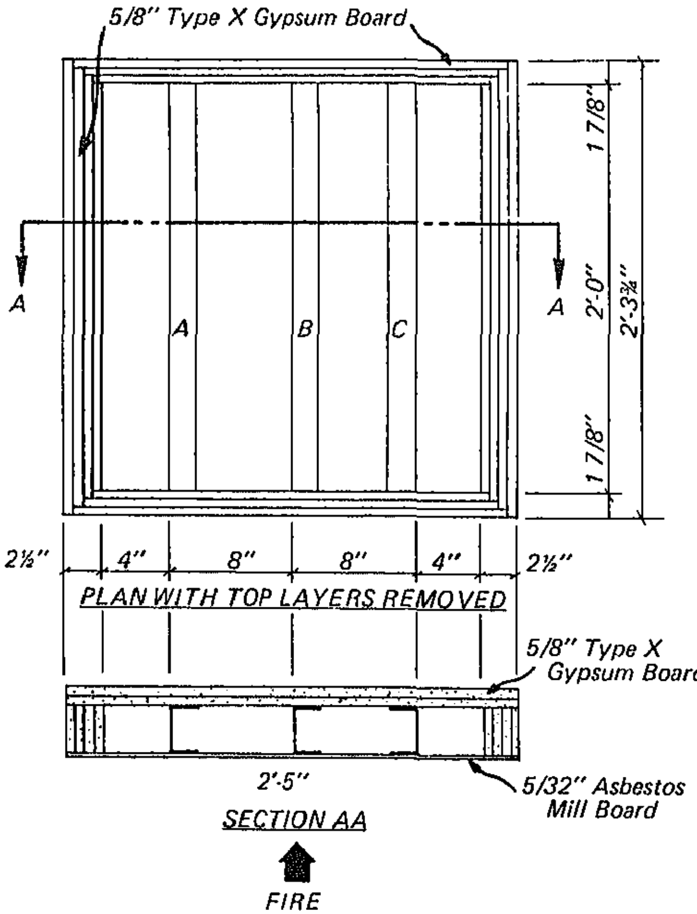
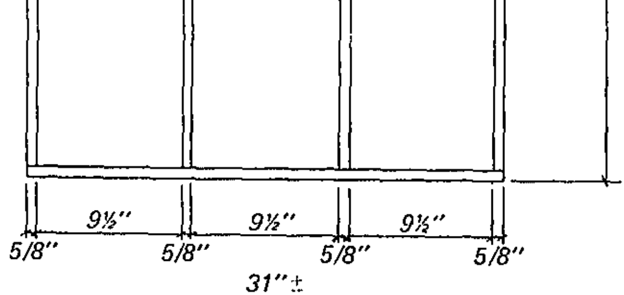
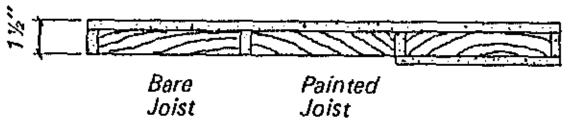


FIGURE 4.4a
Steel Stud Test Specimen



PLAN WITH TOP LAYER OF GYPSUM BOARD REMOVED



SECTION AA

FIGURE 4.4b
Wood Joist Test Specimen

REF: Issen, L. A., *Tests of the Fire Resistance of Intumescent-Painted Structural Elements,* NBS Report 10412, National Bureau of Standards, Washington, D. C. 20234 (NTIS Accession No. PB-213 653).

underlayment combinations and strip flooring applied directly over the j
several tests carpeting was installed as part of the floor system. By using the sa
of construction for several of the small-scale specimens as was used in the
specimens, it was possible to obtain correlations between the results obtai
both types of tests.

The fire exposure conditions used were in accordance with the ASTM
time-temperature curve. Test results were evaluated by means of the AS
endurance criteria for floors described in Section 3.1 of this publication. Ho
the case of the small-scale specimens, the criteria for failure under load
considered, since it was not possible to apply enough load to provide str
equivalent to those provided in the full-scale specimens.

The 2 by 10-in joist framework for each of the twelve small-scale specimens is
Figure 4.5 a. Various combinations of flooring materials were installed on t
25-in framework. A joint was centrally located in each layer of flooring. The
adjacent layers of subfloor and underlayment were perpendicular to each
Tests S-1 and S-2, a 1/16-in joint gap was employed. In subsequent tests, whic
involve tongue and groove plywood, a gap of 1/8 in was used to simulate mo
the cracks caused in the full-scale specimens by the applied loads.

Test Specimen S-1

Specimen S-1 was similar in construction to full-scale specimen L-1, wi
plywood subflooring and underlayment layers and a 1/16-in gap betwe
This specimen was not loaded during the test. Because of some difficulty
furnace control in this first test, the flame-through time was corrected a
to the correction formula in ASTM E 119. *The corrected time of flame*
was 18 min 10 s. Due to the absence of a superimposed load, the cent
joint tended to bend upward because of thermal stress.

Test Specimen S-2

Specimen S-2 was identical to S-1 except for an applied load of 10 lb
bending was observed, either upward or downward, during
Flame-through occurred at 17 min 21 s.

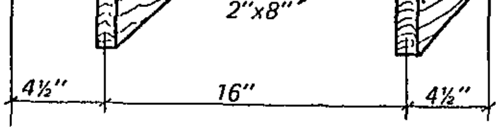


FIGURE 4.5a
Joist Framing for Small Scale Fire Test Specimen

Test Specimen S-3

Test specimen S-3 was identical to S-1 and S-2 except that the gap between joints in subflooring and underlayment was increased to 1/8 in. In this test the superimposed load was increased to 60 lb/ft^2. *Flame-through occurred at 12 min 45 s,* primarily through the joint, which compares well with the 13 min 30 s for full-scale specimen L-1. It is possible that the 1/8-in gap built in during construction of this specimen was comparable to the joint gap in the large specimen that opened up when the specimen was under load.

The 60 lb/ft^2 loading used in S-3 was also used for the subsequent small-scale tests that follow.

Test Specimen S-4

Specimen S-4 was identical to S-3 except that the same type of carpeting and pad used in the large-scale test L-1 were used to cover the underlayment. Flame-through originated in the same area as in Test S-3. The unexposed surface of the carpet charred over a large area during the last 3 min 50 s of test, *with surface ignition spreading rapidly over the char region at 25 min 50 s.* This was considered to be the flame-through time. Some deflection due to load was observed after 21 min of exposure to fire.

Test Specimen S-5

The flooring for S-5 was 25/32-in T & G pine strip flooring applied directly to the joists. *Flame-through occurred at 10 min 30 s through a joint.*

Test Specimen S-8

Specimen S-8 was the same construction as S-4 except that 1/4-ir substituted for the 1/2-in underlayment. Excessive temperature ri 22 min 30 s and *flame-through at 24 min.*

Test Specimen S-9

Specimen S-9 was constructed with 5/8-in tongue and groove ply wood joists. Excessive temperatures occurred over the unexposec min 24 s. The joint started to char and open up at 6 min, and *occurred at 11 min 35 s.* These values are in good agreement witl 5/8-in T and G plywood section of large-scale specimen L-2, descr 3.2.3 in this publication.

Test Specimen S-10

Specimen S-10 was identical to S-7. An excessive temperature rise at 6 min 30 s compared to 8 min for S-7. *Flame-through occurre S-10* compared to 9 min 25 s for S-7.

Test Specimen S-11

Specimen S-11 was identical to S-9 except for the addition of car plywood. An excessive temperature rise was measured at 17 *flame-through occurred at 19 min 20 s.*

Test Specimen S-12

The joist frame for Specimen S-12 was covered with 13/16-in c groove strip flooring. An excessive temperature rise on the unexpo observed at 13 min, and *flame-through occurred at 14 min 10 s.*

While total thermal resistance of the floor system can be used to estimate *flame-through* time or fire endurance, further study is necessary to determine the effects of the superimposed load and the gap size. Both large-scale specimens were tested to failure under load.

The results of both the small-scale and large-scale fire endurance tests on such wood floor constructions are summarized in Table 4.1, thus providing some comparison of the two types of tests.

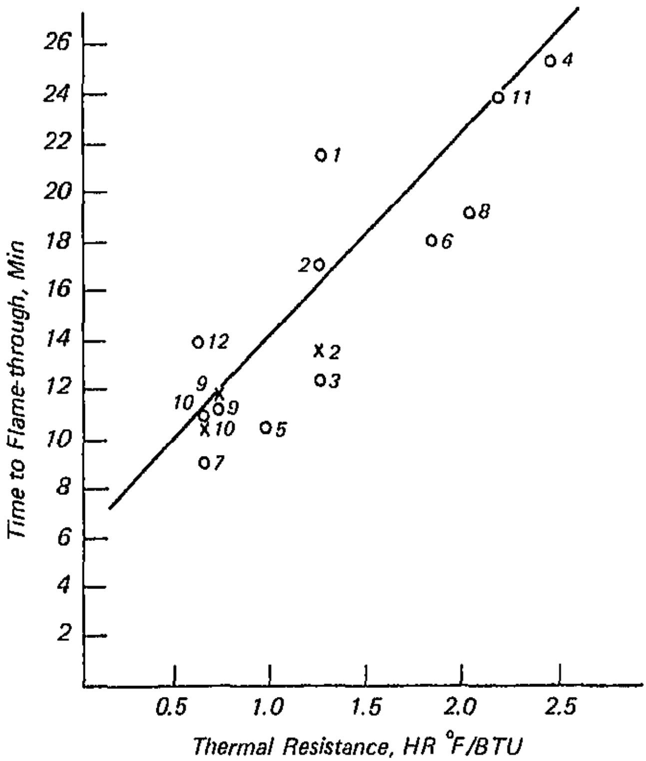


FIGURE 4.5b
Thermal Resistance of Floor Construction vs. Flame-through Time

REF: Son, B. C., *Fire Endurance Tests of Unprotected Wood-Floor Constructions for Single-Family Residences,* NBSIR 73-263, National Bureau of Standards, Washington, D. C. 20234 (NTIS Accession No. PB-225-284/9WB).

TABLE 4.1

COMPARISON OF FIRE ENDURANCE TIMES FOR SMALL AND FULL SCALE TE

Test	Construction	Small Scale Tests (2'x2')				Full Scale	
		Load psf	Flame-thru min : sec	Load Fail min : sec	Temp. Fail min : sec	Load psf	Flan thru min
1	1/2"+1/2" Plywood + 1/16" gap	None	12:43	–	17:10	–	–
2	1/2"+1/2" Plywood + 1/16" gap	10	17:21	–	–	63.7	13:3
3	1/2"+1/2" Plywood + 1/8" gap	60	12:45	–	–	–	–
4	1/2"+1/2" Plywood + 1/8" gap and carpet	60	25:50	–	20:00	63.7	Not reac
5	25/32" T & G pine	60	10:30	–	–	–	–
6	1/2" Plywood + 1/8" gap with 2"x4" blocking and carpet	60	18:15	–	11:30	–	–
7	1/2" Plywood + 1/8" gap with 2"x4" blocking	60	9:25	–	8:00	–	–
8	1/2"+1/4" Plywood with 1/8" gap and carpet	60	24:00	–	22:30	–	–
9	5/8" T & G Plywood	60	11:35	–	10:24	21	11:
10	1/2" Plywood with 1/16" gap and 2"x4" blocking (L-2) or same with 1/8" gap for S-10	60	11:00	–	6:30	21	11:
11	5/8" T & G Plywood and carpet	60	19:20	–	17:15	–	–

composed of 0.10-in thick laminates bonded with a special modified polyester adhesive to the tops and bottoms of truss-type stiffeners made of the same material as the laminates. The size of the panel was 3 ft 4 in by 11 ft 8 in. At each end of the specimen, along the 3-ft 4-in dimension, a nominal 2 by 6-in kiln-dried Douglas Fir edge member was bonded to the upper and lower sheets of laminates with another type of special proprietary adhesive. The panel thickness, therefore, was a nominal 6 in. All

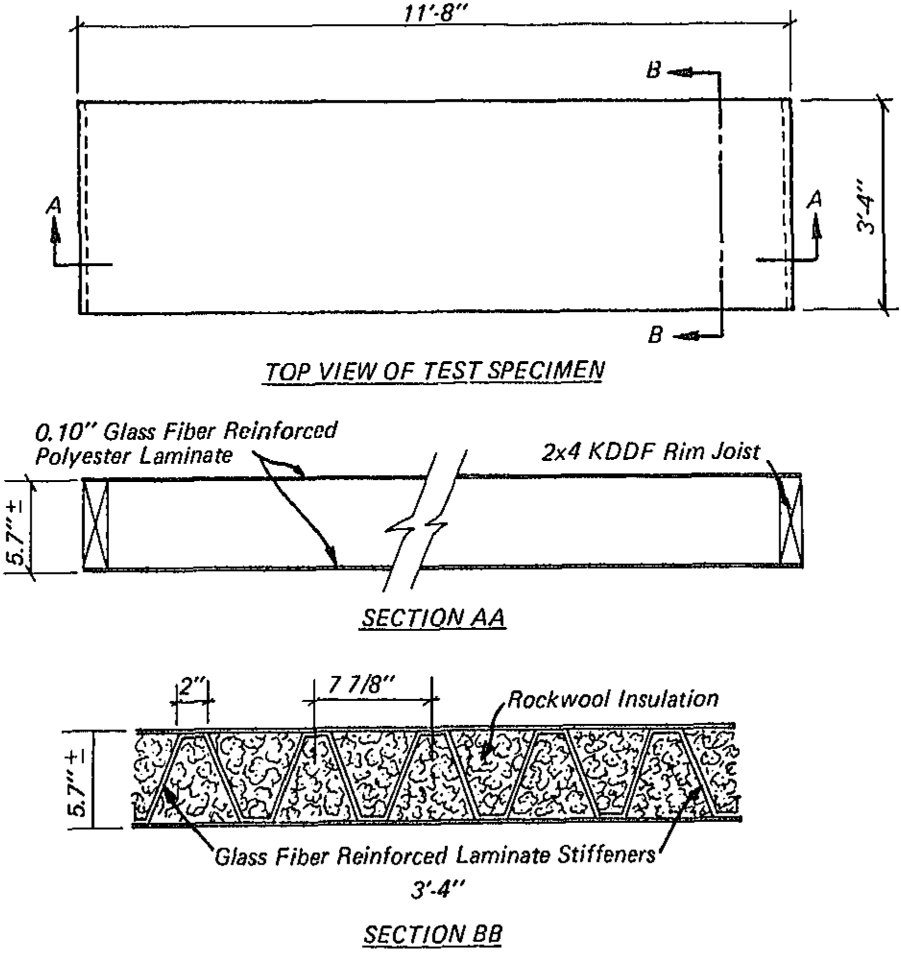


FIGURE 4.6a
Details of Test Specimen

furnace, were tightly filled with rock wool to avoid edge burning. Deflecti
read using a tautly stretched wire with an initial reading of 2 in.

During the first few minutes of exposure the intumescent paint on the expose
blistered, followed by black smoke from the burning laminate and the eventu
off of the exposed skin.

One long edge of the panel was burning and deflecting excessively, while the o
side remained undeflected. The test was stopped at 60 min due to the
deflection along the burned edge. At that point (60 min) none of the therm
on the upper surface showed excessive temperature rise, although there was ev
hot spots in other areas. In view of the erratic and non-uniform behavior of
panel during the test, the results were not considered to be representative of
performance of the construction.

Test No. 2:

Test specimen No. 2 was identical to Specimen No. 1 with the exception that
rock-wool insulation was used instead of the 11 lb/ft^3 insulation, and tes
conducted in an identical manner.

After 3 min 30 s the intumescent paint on the exposed surface began to blis
later, the appearance of black smoke indicated burning of the laminate. At 4
deflection was 2.5 in, and an *oil canning* effect due to thermal stresses was o
At 8 min 30 s most of the exposed (lower) skin fell off, with continuing blac
as the remainder of the skin and the exposed portions of the stiffeners burne
min 30 s the black smoke had abated, and the deflection measured 2.75-in.

The deflection had increased to 3.5 in after 24 min of fire exposure and incre
rate of approximately 1/8 in every two min. At 90 min and a deflection of
the test was terminated with no apparent structural failure, nor had there b
flame-through. None of the thermocouples recorded any excessive tempera
nor were there any observable hot spots.

The performance of the specimens in both Test No. 1 and Test No. 2 indica
intumescent paint is of minor importance in prolonging the fire endurance
systems such as these.

Within 2 min from the start of the test, black smoke was seen, indicating burning of the exposed lower laminate. At 7 min the exposed skins on both sections of panel had burned off, leaving the insulation exposed, at which time a small amount of the insulation fell out. The test was terminated after 45 min of exposure when the deflection had reached 2 1/8 in with no structural failure. No excessive temperature rises on the unexposed upper surface were recorded during the test.

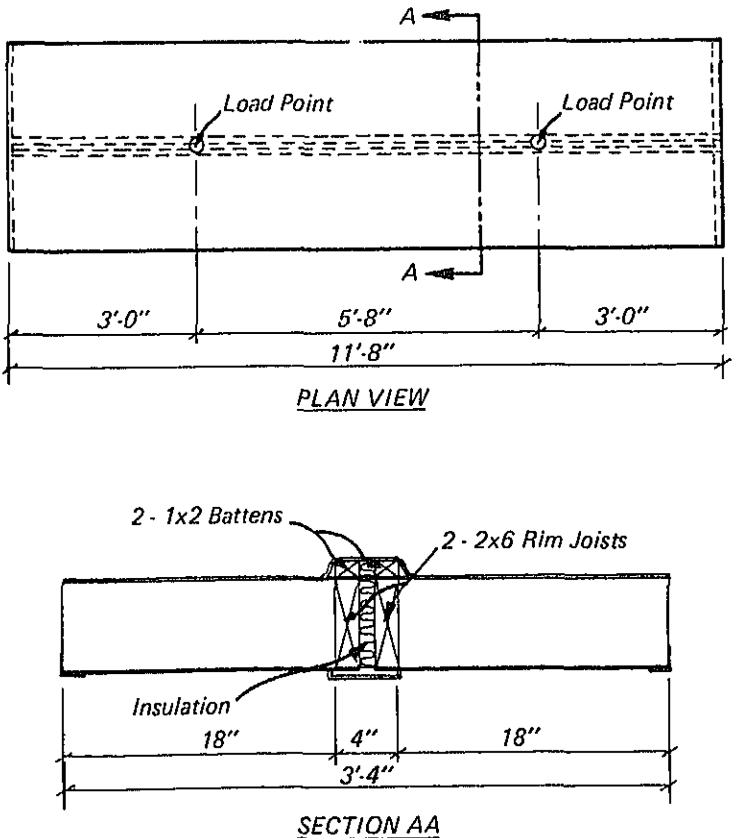


FIGURE 4.6b
Detail of Test Specimen
for Joint Test

REF: Unpublished reports.

5.

SURFACE BURNING CHARACTERISTICS COMPONENTS

fires are attributed to smoke inhalation.

5.1 Test Methods

Because of time and equipment limitations, flame spread (surface flammability) was determined primarily by the ASTM E 162 *radiant panel* test method, although some measurements were made by means of the ASTM E 84 *tunnel* test. ASTM method E 162 allowed the use of small specimens, which were frequently all that were available, and permitted the evaluation of kitchen cabinets whose small size would have made testing by ASTM method E 84 difficult. The two methods give comparable results for most materials, and some building codes use them interchangeably.

In most cases, smoke generation was measured in the NBS smoke density chamber; however, in the few cases where the E 84 test method was used to determine flame spread, smoke generation was also measured by this method.

Carpeting materials were also evaluated by means of the *pill* test, which determines the spread of combustion when a hot object such as a cigarette is dropped on a carpet.

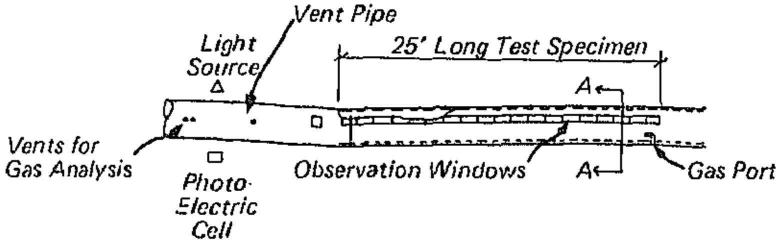
5.1.1 Flame Spread Test Methods

5.1.1.1 ASTM E 84 (Tunnel Test)

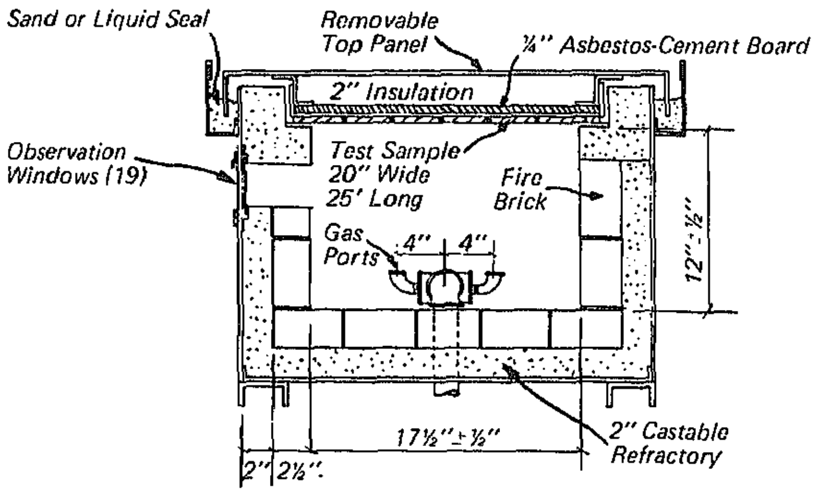
The tunnel test, *Standard Method of Test for Surface Burning Characteristics of Building Materials,* ASTM Designation E 84-70* was originally published as a standard in 1950. It was last revised in 1975. The purpose of the test is to determine the rate and extent of travel of a flame over the exposed surface of the test material. It also provides a means for measuring the fuel contributed and the density of smoke generated.

The size of the fire test chamber or tunnel (Fig. 5.1) is such as to require that the test specimen be at least 20 in wide and 25 ft long. After the test specimen is mounted over the open top of the furnace, the two gas burners are ignited and the flame adjusted in accordance with calibration tests using red oak flooring and 1/4-in asbestos-cement board as standards having

*Part 14, 1971 *Annual ASTM Book of Standards.*



SIDE VIEW



SECTION AA

FIGURE 5.1
ASTM E 84 Test Furnace

related to the rate of heat liberation by the material under test are combined to provide a flame spread index or classification.

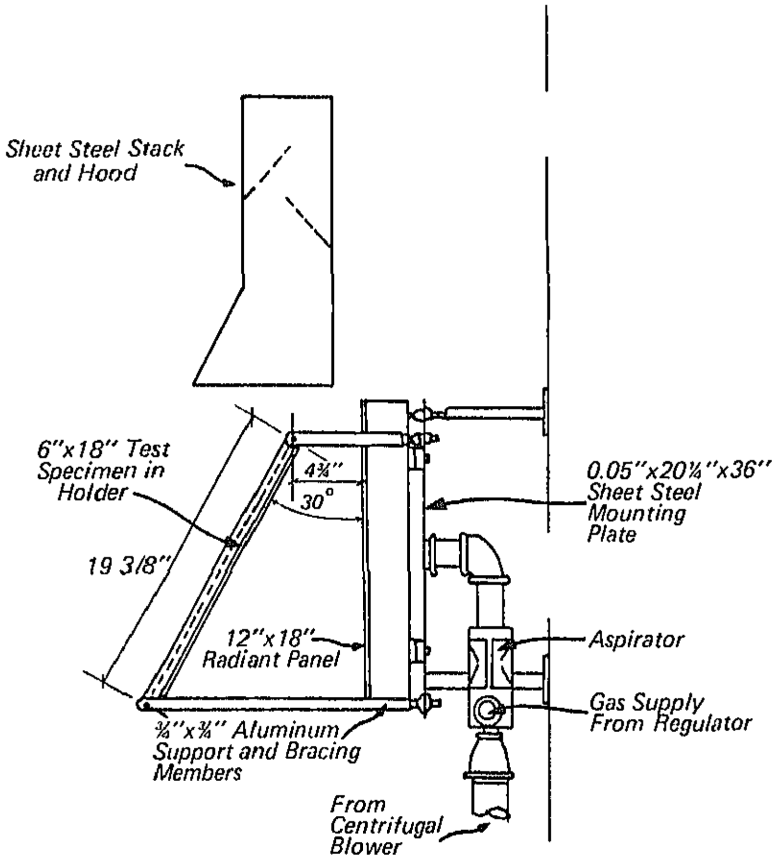


FIGURE 5.2
Test Set-Up for Radiant Panel Test ASTM E 162

* Part 14, 1971 *Annual ASTM Book of Standards.*

material. The inside dimensions of the chamber are 12 by 12 in. Th
the chamber are fastened together with screws or brackets and
prevent air leakage during the test. The bottom of the chamber is
to be easily removable.

The test specimen consists of a 9 by 9-in section of carpet or ru
after the prescribed conditioning, is placed in the center of the flo
chamber and over which a flattening frame is placed. This frame
9-in steel plate, 1/4 in thick, with an 8-in diameter hole in its ce
chamber is placed in a draft-protected environment (hood with draf

A standard igniting device (pill) in the form of a No. 1588 meth
timed burning tablet, or equal, is placed on the test specimen at t
of the 8-in hole in the flattening plate. The tablet is then carefull
and the test permitted to continue until one of the following c
occurs:

(1) The last vestige of flame or glow disappears, or
(2) the flaming or smoldering has spread to within 1 in of the ed
hole in the flattening frame at any point, at which time the sp
considered to have failed the test.

Eight samples are tested for each type of carpet being tested, an
seven of the samples must meet the acceptance criterion.

5.1.2 Smoke Generation Test Methods

5.1.2.1 ASTM E 84

In the few cases where the ASTM E 84 Standard Test Method wa
determine flame spread, the optical density of the smoke generated
measured with the photoelectric equipment that is a part of
apparatus.

*Federal Register, Vol. 35, No. 74, April 16, 1970 and Vol. 3
December 29, 1970.

FIGURE 5.3
Cut-Away of *Pill* Test Apparatus

5.1.2.2 NBS Smoke Chamber

When flame spread was measured by ASTM E 162, smoke generation of the same type of material was measured in the NBS Smoke Density Chamber. The smoke chamber consists of a 16 ga sheet metal box 3 ft wide, 3 ft high and 2 ft deep. As shown in Fig. 5.4, openings are provided for a photometer with a 3-ft vertical light path, power and signal lead wires, air and gas supply tubes, an exhaust blower and damper, an aluminum foil blowout panel and a hinged door with a window. The chamber is tightly closed and usually not ventilated during test. The interior and all parts therein are either anodized black or painted with a flat black paint resistant to corrosive decomposition products.

A 3 by 3-in specimen is ignited either electrically (for non-flaming or smoldering tests) or by a gas jet (for flaming tests). The optical density of the smoke generated is measured by the photometer, thus providing a quantitative measurement of smoke under specific burning conditions (flaming or non-flaming).

REF: Gross, D., Loftus, J. J. and Robertson, A. F., *Method for Measuring Smoke from Burning Materials,* ASTM Special Technical Publication No. 422, 1967, American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa. 19103.

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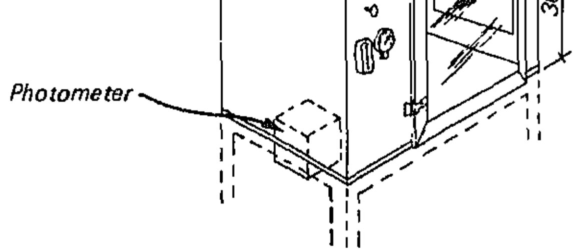

Note: Smoke
rests on steel a
support frame
is mounted a c
panel.

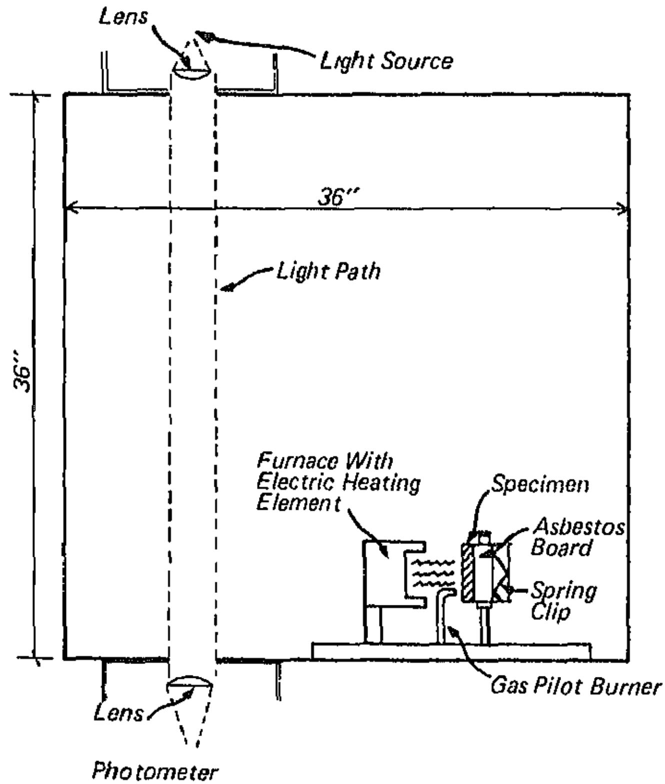

FIGURE 5.4
Details of NBS Smoke Chamber

with ASTM E 162, except where noted otherwise. Where the *Pill Test* was also conducted when carpeting was being tested, the results are noted in the table. The absence of such a note indicates that no *Pill Test* was performed.

5.2.3 Kitchen Cabinets

The broad range of test values for flame spread shown in Table 5.3 were obtained when kitchen cabinet doors and end panels were tested by the radiant panel method, ASTM E 162. Since consistently low test results were obtained for melamine and vinyl-clad kitchen cabinets tested in early phases of the Operation BREAKTHROUGH Program, testing was not required for cabinets coated with these materials that were submitted in latter phases of the program. Smoke generation tests were not conducted, since the ignitability of kitchen cabinets by range fires is considered to be the primary fire safety problem associated with them.

5.1—Summary of Test Results—Wal

Sample Description	Thickness (inches)
A. Glass Reinforced Polyester	
1. Glass reinforced polyester panel (approximately 20% glass and tetra bromo phthalic anhydride flame retardant in polyester resin	0.085
2. Glass reinforced polyester panel (with tertra bromo phthalic anhydride flame retardant in polyester resin)	
Interior Specimen	0.082
Exterior Specimen	0.100
3. Paper honeycomb sandwich wall panel (using glass cloth and polyester resin, having a double thickness of 5/8 inch gypsum board on one side for an interior surface, or having a single 5/8 inch gypsum board together with sand and polyester resin for an exterior surface)	
Interior Specimens	5 1/4
Exterior Specimens	
4. Polyester resin and fiberglass composition sprayed on 3/8 inch plywood (wood stud partition filled in with two layers of foil faced glass fiber insulation sandwiched between two sheets of 3/8 inch coated plywood. The plywood was spray coated with a layer of pigmented polyester resin and fiberglass)	4 3/8

5.1—Summary of Test Results—Wall, Side, and Ceiling Co

Sample Description	Specimen Thickness (inches)	Specimen Density (lb/ft^2)	Fla Spr
5. Laminate of gel-coated fiberglass on 3/4" plywood (smooth white finish)	13/16	3.1	9
Front Face (smooth side)			
Back Face (matted surface)			
6. Fiber glass polyester with intumescent coating (white in color)	1/8	1.6	9
7. Gel-coated fiberglass laminate on 3/4" plywood (front side, smooth white finish; rear side, a rough finish)	25/32	3.1	
Smooth Side			93
Rough Side			95
8. Polyester and chopped glass fiber interior and exterior surfacing material			
Interior	0.125	0.8	99
Exterior	0.200	0.9	14
9. Glass reinforced plastic interior panel	1/8	1.04	7
10. Glass reinforced plastic exterior panel	1.75	0.9	
White			47
Beige			82

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5.1—Summary of Te

Sample Description
11. Polyester resin and fiberglass composition
Brown, rough I Brown, rough II White, smooth White, rough
12. Joint laminate 40% resin, exterior finish
Joint Laminate, 41% resin, exterior finish
Polyester skin, 31% resin, exterior finish
Polyester skin, 34% resin, exterior finish
Polyester skin, 36% resin, exterior finish

5.1—Summary of Test Results—Wall, Side, and Ceiling Coverings

Sample Description	Specimen		
	Thickness (inches)	Density (lb/ft^2)	Flame Spread
B. Cellulose Based			
1. White vinyl cushion wall on paper (with 3/8" plywood backing)	vinyl + paper + plywood film 1/16" + 3/8"	1.7	55
2. Exterior plywood, clear grain plywood	1/2	17*	104
3. Smooth and granular finishes on 3/8" plywood and 3/8" upsum board (smooth white finish on 3/8" plywood, and gray granular finish on 3/8" wood base fiber board and gray granular finish on 3/8" wood base fiber board)			
3/8" plywood, smooth white finish	7/16	1.2	129
3/8" Plywood, gray granular finish	3/8	1.2	165
3/8'' wood base fiber board, smooth white finish	3/8	1.1	128
3/8" wood base fiber board, gray granular finish	7/16	1.1	286
4. Exterior 3/8" plywood on 1/2" gypsum board (stained light green in color)	7/8	2.9	86

*lb/ft^3

5.1—Summary of Test Results—Wall, Side, and Ceiling Covering

Sample Description	Specimen Thickness (inches)	Specimen Density (lb/ft²)	Specimen Flame Spread
5. Particle board with vinyl wall covering (flower design)			
Particle Board Wall Covering	1 1/8 1/64	42.8	63
6. Fiber board ceiling title (fiberboard with interlocking edges, white surface exposed)	1/2	0.8	32
7. 1/2" plywood ceiling panel, with 1/16" layer of fiberglass resin coating on each side	5/8	2.2	60
8. Plywood exterior wall panel (latex painted)	5/8	1.8	72
9. 3/8" rough sawn, grooved 3-ply plywood stapled to 1/2" exterior gypsum sheathing board	7/8	3.08	130**
10. Rough sawn Phillipine mahogany			
5/8" stained	5/8	1.69	80**
5/8" unstained	5/8	1.51	90**
3/8" stained	3/8	1.11	120**
3/8" unstained	3/8	1.05	105**
11. African Mohogany faced, V-grooved, coated plywood	1/4		175**
12. African Mohogany veneer faced, coated V-grooved plywood with 3/8" fire retardant particle b...	7/16		28**

Sample Description	Specimen Thickness (inches)	Specimen Density (lb/ft^2)	Flame Spread
C. Miscellaneous			
1. 1/16" Formica glued to 5/8"gypsum board (light green)	11/16	2.7	18
2. Interior wall partition white asbestos, laminated covering with polystyrene inner panel	4	3.75*	55
Asbestos covering only			30

*lb/ft^3

REF: Ferguson, J. B., *Summary of Flame* *Conducted for Operation* BREAKT National Bureau of Standards, Wash (NTIS Accession No. PB-222 425)

5.2—Summary of Test Results—Floor Coverings

Sample Description	Specimen Thickness (Inches)	Specimen Density (oz/yd^2)	Flame Spread
A. Olefin Carpets			
1. Oliver gold, loop pile with jute backing (mounted on 3/8" plywood with carpet adhesive. The carpet fiber was unidentified "but may have been polypropylene")	5/16	55	295
2. Continuous filament Olefin loop carpet with jute backing; mixed colors of gold, green, and yellow with rubberized hair pad underlayment			408
Rug	3/16	51.3	
Jute	1/16		
Underlayment	1/2	40.0	
3. Continuous filament Olefin loop carpet with jute backing (mixed colors of gold, green, and yellow with rubberized hair pad underlayment)			528
Rug	3/16	51.6	
Jute	1/16		
Underlayment	3/2	44.0	
4. 100% Olefin fiber with jute 1/4 backing carpet (color-green)	1/4	60	
5. 100% polypropylene fiber carpeting with woven jute backing (color-black and gray) or high density			

Sample Description	Specimen Thickness (Inches)	Specimen Density (oz/yd^2)	Specimen Flame Spread
6. Tufted carpet with polypropylene (Primary) and jute (Secondary) backing (mounted on 1/4" asbestos cement board with carpet adhesive)	1/4	56.8	60*
B. Polyamide Carpets			
1. 16 oz. 100% continuous filament nylon looped carpet with polypropylene and jute backing (color-blue and green)			439
Rug	1/8	51.8	
Jute	3/32		
Underlayment	3/8	36.4	
2. 100% Continuous filament nylon looped carpet with polypropylene and jute backing (multicolored-green and black)			482
Rug	1/8	51.8	
Jute	3/32		
Underlayment	3/8	36.4	
3. 100% nylon pile carpet with 3/8" jute backing, with 1/4" rubberized hair underlayment on 3/4" plywood (color-green with sculpture pattern)			180
Rug	3/8	53.7	
Jute	1/8		
Underlayment	1/4	34.5	

*Tested in accordance with ASTM E 84

5.2—Summary of Test Results—Floor Coverings

Sample Description	Specimen		
	Thickness (Inches)	Density (oz/yd^2)	Flame Spread
	34.5		
4. 100% nylon short loop pile carpet with polypropylene primary back and jute secondary backing (tested with and without rubberized hair pad underlayment)			
Rug	5/16	55	
Pad	3/8	26	
With hair pad			
Without hair pad			
5. 100% nylon yellow shag carpet with double jute backing, (tested with and without rubberized hair pad underlayment)			
Rug	.75 to 1.0	69	
Pad	3/8	26	
With hair pad			
Without hair pad			
6. Nylon carpet, level loop polypropylene primary back, jute secondary back with latex coated felt pad underlayment			
Dark Blue (16 oz.)	1/4	62.5	222
Light Blue (28 oz.)	5/16	76	154

Sample Description	Specimen		
	Thickness (Inches)	Density (oz./yd^2)	Flame Spread
7. 100% Nylon continous filament carpeting (orange, with 2 ply backing of 3.5 oz. polypropylene primary and 7 oz. jute secondary ply)	9/32	69	203
8. Nylon shag carpet with 1/4" integral foam rubber backing (mounted on 3/8" plywood)		1.6** includes 3/8" plywood	311
Shag	1		
Rubber	1/4		
Plywood	3/8		
9. 100% nylon (20 oz.) carpet with jute backing; gold in color and mounted on 5/8" plywood, on 3/8" foam underlayment			246
Rug	17/32	20	
Jute	3/32		
Underlayment	3/8		
10. 100% nylon (20 oz.) carpet with high density foam backing, gold in color, 1/8" 38 oz. foam underlayment on 5/8" plywood substrate			270
Rug	17/32	20	
Foam backing	1/8	38	
11. 100% continuous filament nylon shag carpet with 3/8" foam backing (blue and green in color)			260
Pile	1 1/4	83	
Foam	3/8		

** lb/ft^2

5.2—Summary of Test Results—Floor Coverings

Sample Description	Specimen Thickness (Inches)	Specimen Density (oz/yd^2)	Specimen Flame Spread
12. 28 oz. 100% continuous filament nylon looped carpet with polypropylene and jute backing (mixed colors, orange and green)			359
Rug	5/16	59.5	
Jute backing	3/32		
Underlayment	3/8	36.4	
13. 20 oz. 100% nylon clipped loop carpet with polypropylene and jute backing (color-green)			276
Rug	3/8	57.6	
Jute	3/32		
Underlayment	3/8	36.4	
14. Nylon (continuous filament) tufted carpet with polypropylene (primary) and jute (secondary) backings (mounted on 1/4" asbestos cement board with carpet adhesive)	7/32	59.1	70*
15. 16 oz. nylon carpet, level loop, with polypropylene (primary) and jute (secondary) backing and latex coated felted pad underlayment (mounted on 1/4" asbestos-cement board with carpet			

Sample Description	Specimen Thickness (Inches)	Specimen Density (oz/yd²)	Specimen Flame Spread	Sm… Flami…
16. 28 oz. nylon carpet, level loop, with polypropylene (primary) and jute (secondary) backings and latex coated felted pad underlayment (mounted on 1/4" asbestos-cement board with carpet adhesive)			210*	595
Rug	5/16	81.1		
Underlayment	5/16	41.6		
C. Miscellaneous				
1. Gold hi-lo carpet, rubber backing	1/2	68.4		
With 5/8" plywood backing				311
Without 5/8" plywood backing				361
2. Vinyl floor covering on 3/4" plywood (1/64" vinyl backed with 1/16" cardboard; color-light brown and green with rough surface)	57/64	3**	70	181
3. Vinyl floor covering, color yellow, green, and brown	0.065	42	350	185
4. Vinyl Sheet Flooring				
Brand X	0.075	37		529
Brand Y	0.075	35.9		244
5. Vinyl floor covering 1/16" thick, underlayment-3/8" flakeboard	7/16	1.7**	72	767
6. Vinyl floor covering (mounted on 1/4" asbestos board with adhesive)	0.150	75	137	617

* Tested in accordance with ASTM E 84

REF: Ferguson, J. B., *Summary of Flame Spread* … *Conducted for Operation* BREAKTHROUG… National Bureau of Standards, Washington…

5.3—Summary of Test Results —Kitchen Cabinets

Sample Description	Specimen	
	Thickness (inches)	Density (lb/ft^2)
1. Kitchen cabinet doors with plastic outer finish and paper honeycomb interior (brown in color)	3/4	1.2
Outer Plastic	1/16	
Honeycomb paper	5/8	
2. Kitchen cabinet end panels with plastic and lacquer finish on 1/8" poplar with 1 1/2" x 3/4" white pine batten (brown in color)	7/8	0.5
Panel	1/8	
3. Particle board core door and end panels; doors with polyester laminate overlap and panels with birch veneers		
Doors	1/2	52**
End Panels	1/2	46**
4. Simulated woodgrain kitchen cabinet doors and end panels (color brown)		
End Panels	1/8	57.6**
[illegible]	7/16	75**

Sample Description	(inches)	(lb/ft^2)	Fla
5. Plywood Kitchen cabinet doors and end panels (door panels plywood, with dark brown wood grain veneer-lacquer finish; end panels, plywood with dark brown wood grain veneer).			
Door panel	3/4	2	
End panel	3/4	2.2	
6. Plywood kitchen cabinet door and end panels (rerun of number 5 above)			
Doors	3/4	1.8	
End panels	3/4	2.0	
7. 3/16" mohogany plywood kitchen cabinets, and end panels with Melamine woodgrain veneer on one side.	3/16	0.75	
8. 3/4" plywood kitchen cabinet door panel (color-light brown finish).	3/4	2	
9. Composition wood door panel for kitchen cabinets with 1/32" wood grain veneer on both sides (color-dark stained finish).	7/16	2.2	
10. Particle board with vinyl clad walnut wood grain finish kitchen cabinet doors (5/8") and end (3/8") panels			
Door panels	5/8	2.6	
End panels	3/8	2.0	
11. Particle board kitchen cabinet doors and end panels (door panel 3/8" wood grain finish on both sides; end panel 1/2" varnish on both sides, wood grain on exterior).			
Door panels	3/8	2.6	
End panels	1/2	2.2	

REF: Ferguson, J. B., *Summary of Flame Spread and Smoke Gen*
Conducted for Operation BREAKTHROUGH, NBSIR 73-2

6.

OTHER TESTS

8.8 Rate of Heat Release . . . .

release.

6.1 Fire Resistance of Roof Covering Materials

Many fires are spread by means of burning embers blown onto a roof from nearby fires. For this reason, most building codes require that roofing materials possess a certain degree of fire resistance. Fire resistant roof covering systems are grouped into three different classes: Class A (resistant to severe fire exposure), Class B (resistant to moderate fire exposures), and Class C (resistant to light fire exposures), on the basis of their performance when subjected to the three separate tests described in detail in ASTM E 108 and UL 790. Class C ratings are generally required for single family dwelling roofs in areas covered by building codes; however, codes covering high fire risk in congested residential areas frequently have more stringent requirements.

Since one of the Operation BREAKTHROUGH single family housing systems incorporated a glass fiber reinforced polyester resin roof assembly whose fire resistance was not known, tests were conducted to determine its ability to meet the requirements for a Class C rating.

The roof panel construction is described in detail in Section 3.2.1 of this publication. The Class C test conditions specified in ASTM E 108 for (1) intermittent flame exposure, (2) spread of flame, and (3) exposure to burning brands were used.

The basic fire-test apparatus is shown in Figure 6.1a. It consists of a test deck to which the roof covering is applied, a framework on which the test deck is mounted at the prescribed incline, a gas burner, and a variable-speed blower and air duct for producing the requisite wind conditions. Additional equipment consists of gas burners for igniting burning brands, a velometer for measuring wind velocity, a draft gauge for measuring gas pressure and a stop watch for measuring the duration of the test.

In the *Intermittent Flame Exposure Test,* the roof covering materials are mounted on a 4 1/3-ft long roof deck at an angle in a 12±0.5 mph uniform air current flowing parallel to the sides of the deck. Built-up roofs are mounted on the maximum slope recommended by the manufacturer; for shingles and roll roofing products, the test deck is set at a slope of 5 inches of rise per horizontal foot. After the blower is adjusted to produce the specified 12 mph air current, the test roof deck is subjected to

Class A	1400 ± 50	2	2	15
Class B	1400 ± 50	2	2	8
Class C	1300 ± 50	1	2	3

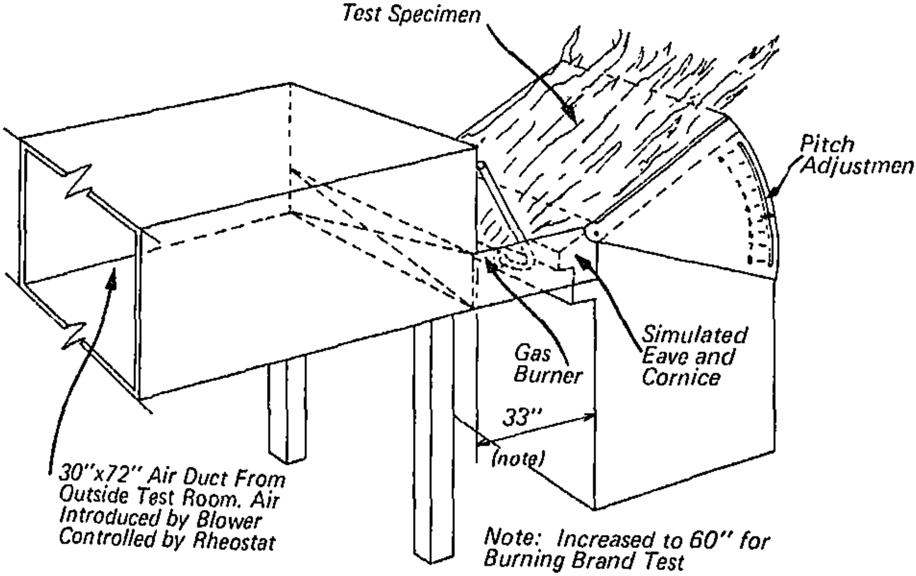

FIGURE 6.1a
Schematic of Fire Test Apparatus

In the *Burning Brand Test* a 4 1/3-ft long test deck is mounted in the same manner as described for the intermittent flame test, except that the framework is 60-in from the air duct outlet instead of the 33-in specified for the intermittent flame test, and the gas piping and burner are removed so as not to obstruct the air flow. Pine or fir brands differing in size and construction details for each class of test (see Figure 6.1b for brand construction details) are placed on the test roof deck in specified locations and then fanned with a 12±0.5 mph wind. One brand is placed at the location considered most vulnerable for class A tests; for Class B, one brand is placed at each of the two locations considered most vulnerable, and for Class C, 25 brands are placed on the deck at 1 or 2-min time intervals. Each individual test is continued either until the brand is consumed and until all evidence of flame, glow and smoke has disappeared from both the exposed surface of the material being tested and the underside of the test deck, or until failure occurs. Criteria for failure are: (1) the appearance of sustained flame on the underside of the test roof deck for Classes A and B; for Class C tests there may be sustained flaming on the underside of the deck for not more than 5 of the 25 brands, (2) the production of flying, flaming or glowing brands that leave the deck, or (3) the displacement of portions of roofing on the deck resulting in deck exposure.

From the results of the three types of tests conducted, it was concluded that the roofing system met the requirements for Class C rating. During the intermittent flame test neither of the specimens tested indicated smoking or deep char penetration of the material; only minor surface blistering was observed. In addition, the undersides of both test decks remained intact, and there was no sensation of warmth at any time during the test. During the spread of flame tests, surface blistering was observed; however, the spread of flame did not exceed 5 ft, and there was no smoking, fall-off, breaking, or production of flying brands from the roof material itself. Observations made during the burning brand tests showed the absence of any flaming on the underside of the test deck, or fall-off or fire brand activity from the roofing material itself.

REF: Williamson, R. B. and Kwan, Q., *Structural Research Laboratory Report* No. 72-10, University of California, Berkeley, California, August 1972. (Unpublished)

Standard Methods of Fire Tests of Roof Coverings, E-108-58, *ASTM Book of Standards,* Part 18.

Tests for Fire Resistance of Roof Covering Materials, UL 790, Underwriter's Laboratories, Inc.

1/8" Saw Kerfs

FIGURE 6.1b
Fire Brands for Classes
A, B, and C Tests

6.2 Flame Propagation from a Room to Exterior Surfaces

In buildings such as townhouses and garden apartments, exterior walls are frequently erected perpendicular to a wall containing a window opening near the reentrant corner. When exterior walls in this configuration are composed of combustible material, it is possible for fire to spread from an interior room to the adjacent combustible exterior walls through the windows. The two full-scale fire tests described in this section were conducted to evaluate Operation BREAKTHROUGH criteria dealing with the problem of reentrant wall corners.

The basic reentrant corner test assembly, which is shown in Figure 6.2, consisted of a burn room in which wood cribs were ignited to simulate the radiation and convection conditions that would occur in an actual fire, and two exterior wall specimens erected perpendicular to a wall containing a window leading into the burn room. The walls and ceiling of the burn room were lined with one layer of 5/8-in thick type X gypsum wall board sprayed with vermiculite plaster and secured with 3/8-in bolts.

Since some damage occurred to the concrete burn room floor during the first test, the floor was covered with refractory sand over which fire brick were placed for the second test. The two exterior wall specimens were erected on each side of the window opening, which was 24 in by 38 in in the first test, and 32 in by 38 in in the second test. One wall was located 1 ft to one side of the window opening for both tests, and the other wall was 5 ft away from the other side of the window opening for the first test and 4 ft 4 in away for the second test. Each wall was 12 ft long and 16 ft high and composed of single layer of 1/2-in thick A-C grade exterior plywood in 4 by 8 ft sheets installed over a layer of gypsum board backing. The plywood, which was selected as being representative of a typical exterior wall finish material, had a flame spread index of 103, as measured by the radiant panel test method described in Section 5.1.1.2. Instrumentation consisted of 32 thermocouples placed on the wall closest to the window opening, 12 thermocouples located on the other wall, 4 thermocouples located in the burn room, and 2 radiometers and a radiation pyrometer, whose locations are shown in Figure 6.2.

tal amount of heat energy absorbed at the exposed surface of the plywood wall prior ignition were estimated to be approximately 1.0 W/cm^2 and 175 J/cm^2, spectively. No ignition was observed for the wall located farther away from the ndow (4 1/2 ft to 5 ft).

the basis of this testing, it was concluded that the choice of a limiting flame spread dex of 75 for exterior wall surface materials in a reentrant wall corner configuration s reasonable.

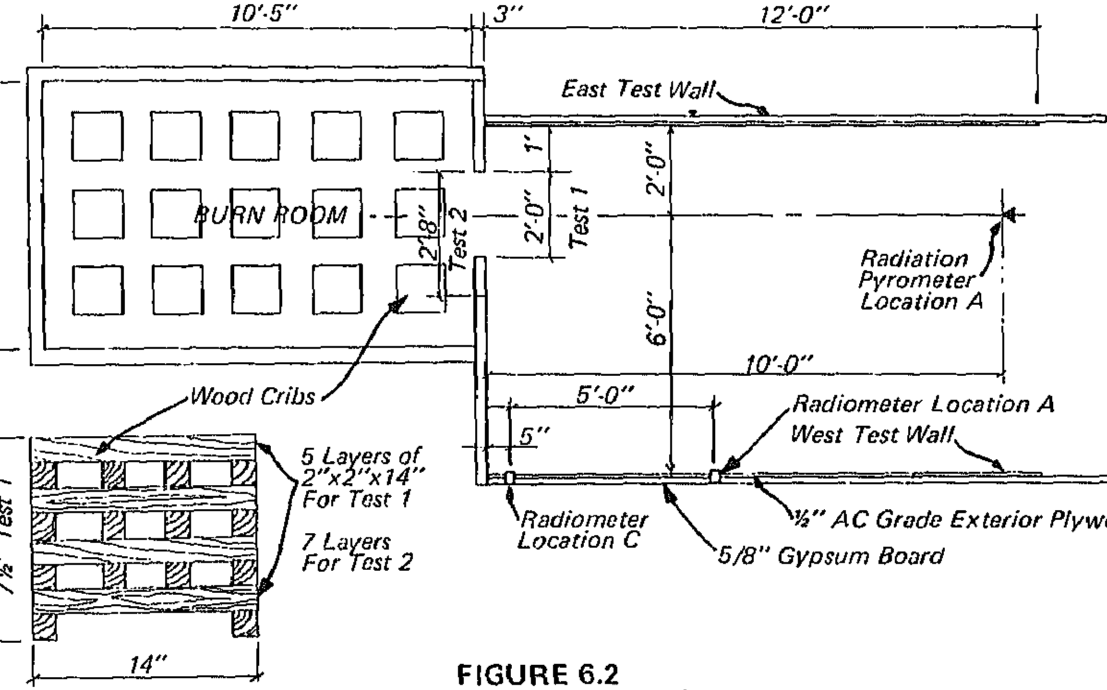

FIGURE 6.2
Plan of Burn Room and Test Wall Layout

REF: Son, B. C., and Fang, J. B., *Fire Spread on Exterior Walls Due to Flames Emerging from a Window in Close Proximity to a Reentrant Wall Corner,* NBSIR 73-266, National Bureau of Standards, Washington, D. C. (NTIS Accession No. PB-225 286/4WB).

HSP elected to use a modification of NRC Method III, *Pressurized Vertical Shafts.* In this method, the following conditions apply:

1. The stair enclosure chosen to be the smoke-proof enclosure shall have equipment capable of providing a mechanical air supply into the shaft at the upper end of not less than 15,000 cfm, plus:

    a. 100 cfm for each door (having a perimeter of not more than 20 ft) that is equipped with a tight-fitting weatherstripping, or

    b. 200 cfm for every other door (having a perimeter of not more than 20 ft) into the stairshaft.

2. Each stairshaft shall have a vent at street level, opening either directly outside or into a vestibule or corridor that has similar opening to outside, having an opening of not less than 0.5 sq ft for every door that opens into the shairshaft, other than doors at street level, but in any case not less than 20 sq ft.

3. The vent at the bottom of the stairshaft may be provided with a window, shutter or door, which shall open automatically, unless there is a central control facility from which the window, shutter or door may be open manually, and shall be designed to remain in the open position during the fire emergency.

4. Manual or automatic operation of a fire alarm box on any floor shall initiate the mechanical air supply to the smoke-proof stair enclosure, as provided in (1) above and shall cause the window, shutter, or door to open as provided in (3) above.

For the 12-story building in which the tests were conducted, the basic air supply to the smoke-proof stair enclosure was set at 10,000 cfm instead of the 15,000 cfm stipulated above. Weatherstripped doors were used on the smoke-proof stair enclosure, thereby reducing additional air supply needed for door leakage from 200 cfm to 100 cfm per door. As a result, the total air supply provided by the HSP was approximately 11,200 cfm, made up of 10,000 cfm plus 1,200 cfm for door leakage.

r the introduction of the SF_6 gas.

test was first performed with a simulated fire on the second floor (see Figure 6.3b floor plan details) and then with a simulated fire on the ninth floor, whose layout quite similar. In addition to determining the smoke infiltration rate with the

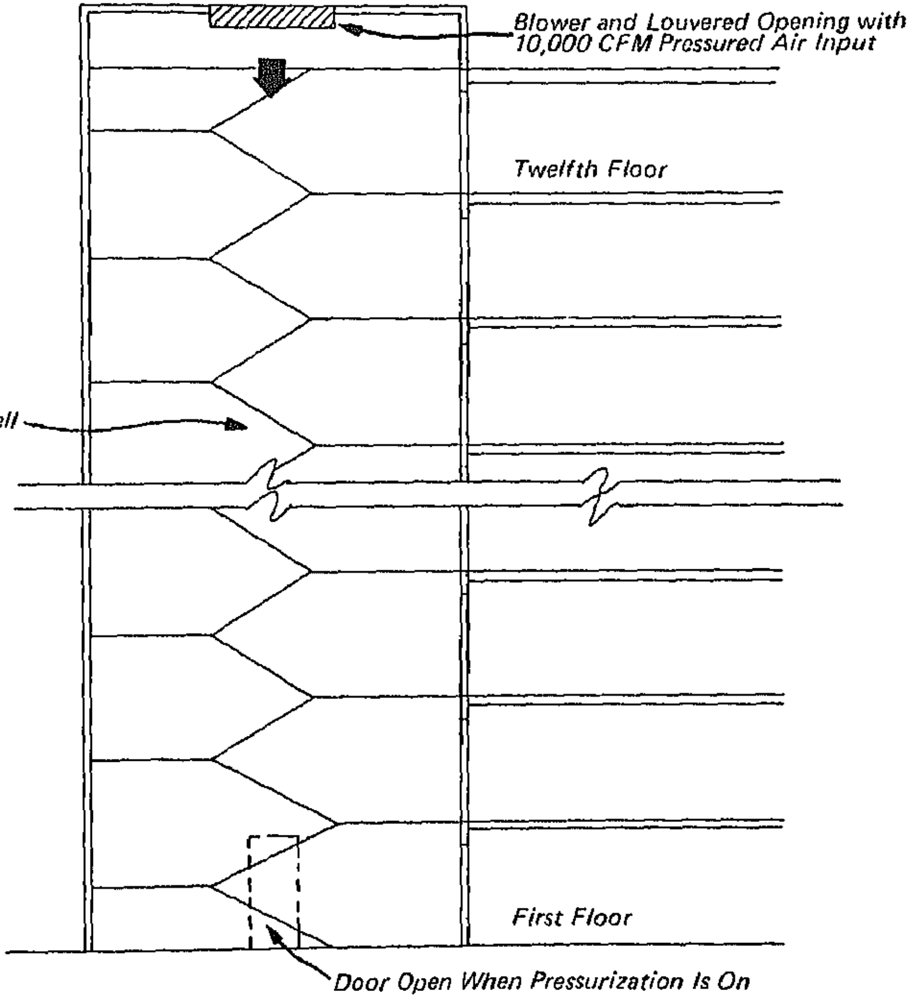

FIGURE 6.3a
Pressurization Flow
Supply and Vent

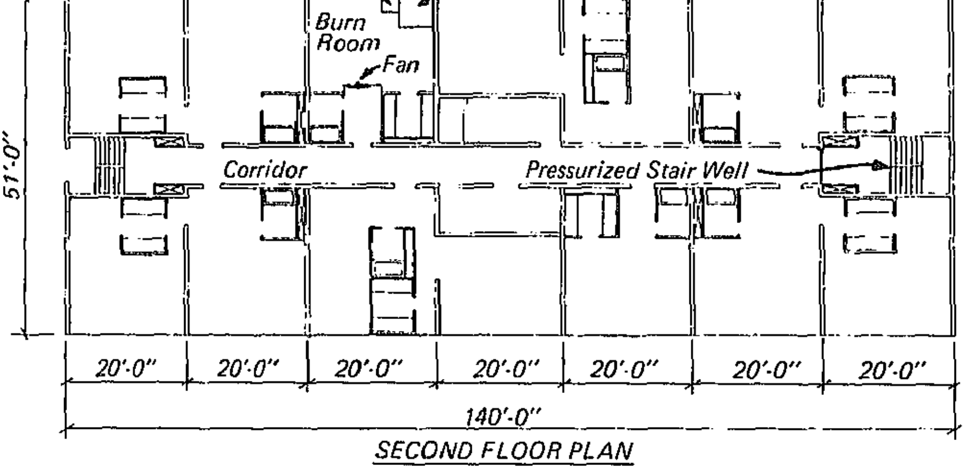

FIGURE 6.3b
Floor Plans of Test Building

stairwell pressurized and all of the exit doors closed, the effects of leaving doors open were determined.

Smoke levels of less than 0.1% were found in the stairwell in all of the tests conducted with the pressurization system on. This included a test in which doors on second, ninth and eleventh floors were left open. A good idea of the effectiveness of the smoke control system can be obtained by comparing the test results found for two tests. In one test, a fire was simulated on the second floor; the stairwell door on this floor was left open, and the pressurization system was left on. In the second test, all test conditions were the same, except the pressurization system was shut down. The simulated smoke levels in the stairwell during the first test were less than 0.1%; in the second test, they ranged from 4 to 70%.

On the basis of these tests, it was concluded that the stairwell pressurization system used was very effective in preventing smoke from entering stairwells, even with several doors open.

REF: Fung, F. C. W., *Evaluation of a Pressurized Stairwell Smoke Control System for a 12-Story Apartment Building,* NBSIR 73-277, National Bureau of Standards, Washington, D. C. (NTIS Accession No. PB-225 278/IWB)

n a medium rise building. The window wall was of steel stud construction, -in gypsum board facing on the building interior side and aluminum clad anels on the exterior side. The 5/16-in thick exterior grade Douglas Fir xterior panels were faced with acrylic enamel coated 10 mil aluminum sheets eather exposed (building exterior) surfaces and with 2 mil aluminum foil on posed surfaces. Spaces between the studs were filled with full-thickness glass tion.

c flow diagram of the test method, Figure 6.4, shows the steps involved in g the potential heat of a material. Two samples are removed from the be tested. One of these is pulverized, pelleted and then burned in a high xygen bomb, yielding a measure of the gross heat of combustion. The other shed in a muffle furnace at 750°C, and the residue is ground or pulverized. of the ash corresponding to a known weight of the original material is mixed mbustion promoter, pelleted and burned in the combustion bomb. After for the heat produced by the combustion promoter, the difference in ues of the two specimens is reported as the potential heat.

data obtained by measurements of this type, the potential heat of the exterior window wall was determined. Values of 8,320 Btu/ft^2 for the faced plywood panelling, 630 Btu/ft^2 for the insulation and 1,380 Btu/ft^2 psum wall board were calculated, yielding a total potential heat value of /ft^2 for the window wall system.

value was higher than the value recommended for exterior walls in the BREAKTHROUGH Guide Criteria, the ease of ignition and rate of heat asurements described in Sections 6.5 and 6.6, respectively, were investigated ecision was made as to the relative fire safety of the wall system.

REF: Bright, R. G., National Bureau of Standards, Washington, D. C. (Unpublished communication), July 13, 1971.

Loftus, J. J., Gross, D., and Robertson, A. F., *POTENTIAL HEAT—A method for Measuring the Heat Release of Materials in Building Fires,* Proceedings of the American Society for Testing and Materials, *61*, 1336. (1961)

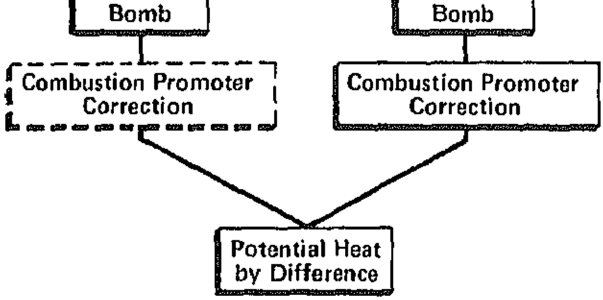

FIGURE 6.4
Schematic Flow Diagram for
Potential Measurements

6.5 Ease of Ignition

The ease with which a material can be ignited is dependent on factors such as its dimensions, the incident heat flux and environmental conditions such as air composition, air temperature and air velocity. The test described in this section was designed to evaluate building materials in contact with flames from incidental or low-energy fires, such as might be expected when a wall is exposed to the flames from a wastebasket fire adjacent to it.

The test was used in combination with potential heat and rate of heat release determinations (see Sections 6.4 and 6.6) to ascertain the acceptability of an exterior wall-cladding material proposed by one of the Operation BREAKTHROUGH Housing System Producers.

The basic test apparatus is shown in Figure 6.5 a. Two 6 by 6-in specimens, each clamped to a backup asbestos-cement board 9 in high by 6 in wide and 3/4 in thick, face each other with a 3/4-in gap between them. The lower edge of each specimen is flush with another asbestos-cement board having the same thickness as the test specimen, which serves as a noncombustible extension of the specimen surface.

A specially designed burner supplied with city gas at a flow rate of 15 ft^3/ min is located 3 in below the lower edge of the specimens. When the gas-air mixture is ignited, a flame passes between the specimens and about 6 in above them.

il did not separate from the plywood, and no ignition was observed during the test.

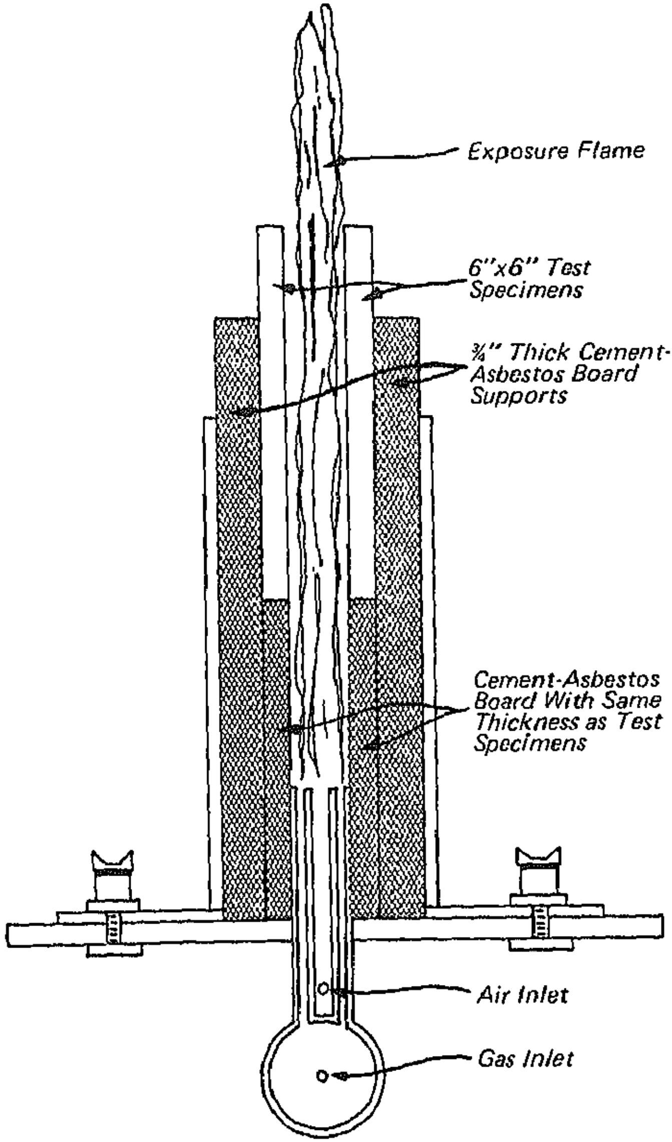

FIGURE 6.5a
Test Apparatus for
Ease of Ignition Test

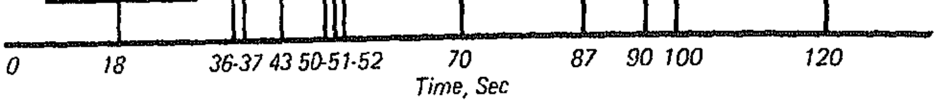

FIGURE 6.5b
Exposure Time Required for Sustained Ignition

REF: Bright, R. G., National Bureau of Standards, Washington, D.C. (Unpublished Communication), July 13, 1972.

Parker, W. J., *The Development of a Test for Ease of Ignition by Flame Impingement,* NBS Report 10468, National Bureau of Standards, Washington, D.C.

6.6 Rate of Heat Release

The rate at which a burning material releases heat in a fire environment is an important characteristic of that material and should be considered when specifying its use in a particular construction. In a room fire, a large portion of the heat released is absorbed in the walls and ceiling. The attendant rise in temperature creates radiation levels which serve to increase flame-spread rates, produce new ignitions, and further increase the rate of heat release of the burning materials. This phenomenon is commonly referred to as flashover. In order to properly evaluate the performance of a combustible material in a fire environment, the rate of heat release as a function of both the time and environmental conditions, including the irradiance level, the air velocity past the surface, the air temperature, and the chemical composition of the air must be known.

The rate of heat release calorimeter test described in this section was used in combination with potential heat and ignition time determinations (see Sections 6.4 and 6.5) to ascertain the acceptability of an exterior wall-cladding material proposed by one of the Operation BREAKTHROUGH Housing System Producers.

admitted through the porous plates into the control chamber to reduce the temperature of the stack gases to a manageable level, and to minimize the errors associated with combustion products of various enthalpies. The high velocity air passing into the chamber through the porous plates also serves to block out heat transfer through the side walls of the chamber. The gas flow to an auxiliary burner located near the center of the control chamber is automatically controlled so that the average temperature of the gases passing up into the mixing chamber remains constant. By this means, the amount of heat produced by the burning specimen is exactly compensated for by a reduction in the amount of heat produced by the burner. The rate of heat release of the specimen is measured by recording the reduction in gas flow to this burner.

A 4 1/2 by 6-in asbestos-cement board reference blank is inserted into the specimen holder and oriented vertically in the center of the combuustion chamber, and a stable base line is thus established prior to inserting a test specimen of the same size.

A peak heat release rate of 9 to 10 Watts/cm^2 was observed when the exterior face of the test specimen was exposed to a heat flux of 6 Watts/cm^2. This corresponds to a fire temperature of 730°C (1346°F). There was an initial delay in ignition, but after separation of the aluminum sheet from the plywood, the heat release rate from the escaping gases was comparable to unprotected wood. The aluminum foil protecting the interior face of the plywood did not delaminate during the test, and no heat release was observed.

These values can be compared to values of 7-8 W/cm^2 for 1/2-in insulating fiber board, 10.3 W/cm^2 for 3/4-in pine, 10.7 W/cm^2 for 3/4-in plywood, 12.5 W/cm^2 for 3/4-in oak and 15.2 W/cm^2 for 3/8-in particle board.

REF: Bright, R. G., National Bureau of Standards, Washington, D. C. (Unpublished Communication), July 13, 1972.

Parker, W. J. and Long, M. E., *Development of a Heat Release Rate Calorimeter at NBS,* NBS Report 10462, National Bureau of Standards Washington, D. C.

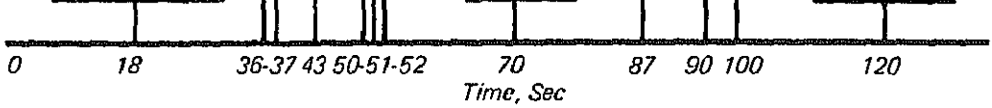

FIGURE 6.5b
Exposure Time Required for
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REF: Bright, R. G., National Bureau of Standards, Washington, D.C. (Unpublishe Communication), July 13, 1972.

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A 4 1/2 by 6-in asbestos-cement board reference blank is inserted into the specimen holder and oriented vertically in the center of the combuustion chamber, and a stable base line is thus established prior to inserting a test specimen of the same size.

A peak heat release rate of 9 to 10 Watts/cm^2 was observed when the exterior face of the test specimen was exposed to a heat flux of 6 Watts/cm^2. This corresponds to a fire temperature of 730°C (1346°F). There was an initial delay in ignition, but after separation of the aluminum sheet from the plywood, the heat release rate from the escaping gases was comparable to unprotected wood. The aluminum foil protecting the interior face of the plywood did not delaminate during the test, and no heat release was observed.

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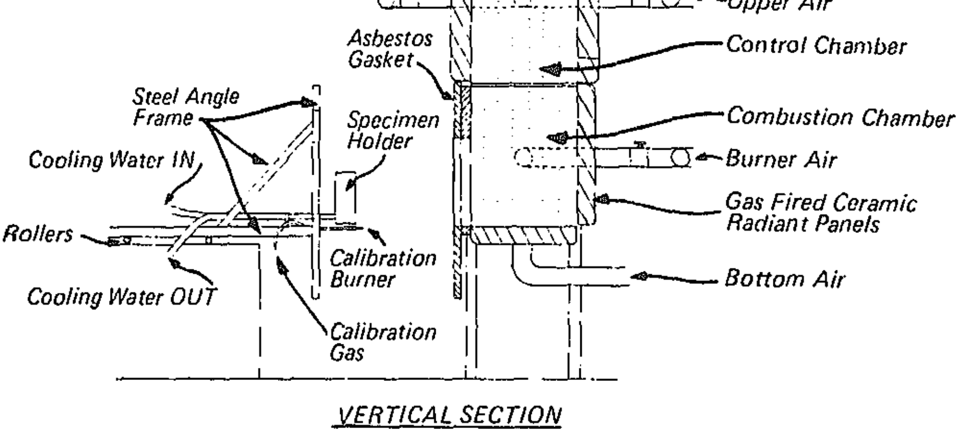

FIGURE 6.6
NBS Heat Release Rate Calorimeter

acknowledgments

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